Introduction

The Body Collected

Tybjerg, Karin

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Den Saxtorphske Samling

Meyer, Ion

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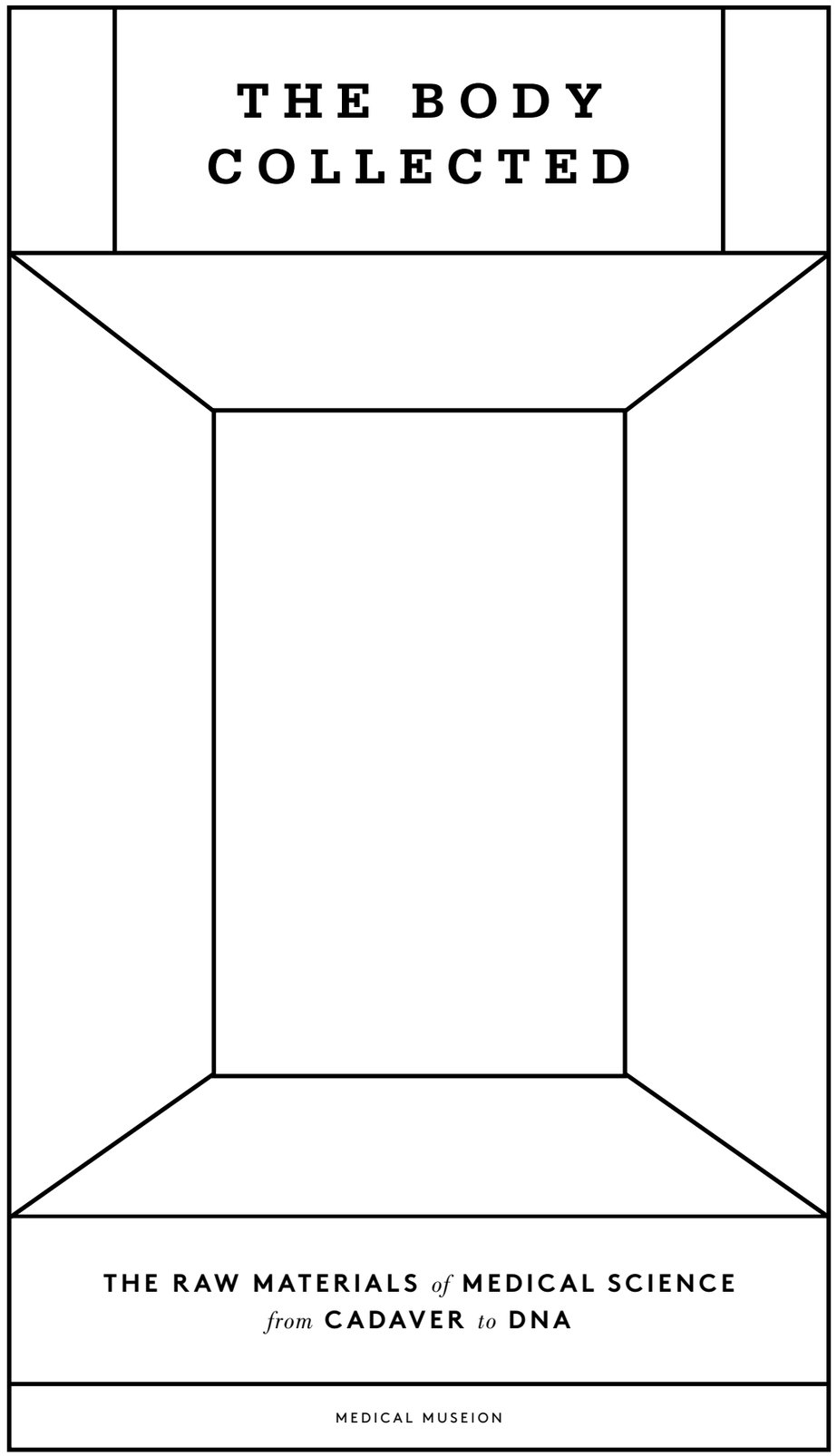
THE BODY COLLECTED


THE BODY
COLLECTED
THE RAW MATERIALS of MEDICAL SCIENCE
from CADAVER to DNA
MEDICAL MUSEION

THE BODY COLLECTED

First published 2016

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FOREWORD

■ When the University of Copenhagen's medical history museum changed its name to Medical Museion a decade ago, one of our main ideas was to bridge the past and the present. Bridge the beautiful and horrific yet immediately graspable human specimens from days gone by, and the high-tech, abstract and more sterile objects of contemporary biomedical research and practice. The scalpel on the one hand, the gene chip on the other.

Over the past ten years and after as many exhibitions, we have adhered to the mantra of the past and the present [and a bit of the future]. This is also true of *The Body Collected*. The basic idea behind the exhibition is to build a conceptual bridge between the striking historical collection of foetuses and organs in jars, which are now almost solely of cultural historical value, and the collections of tissue, cells and molecules that are stored in biobanks worldwide today. Collecting then and now.

The Body Collected also lives up to another of the museum's core ideals, which is letting physical objects take command of our senses and experiences. Texts are not to be scorned, but their primary realm is books, articles and tablets. At Medical Museion the very stuff of life and death remains more important than text.

Thomas Söderqvist, Professor
Museum Director, 1999-2015

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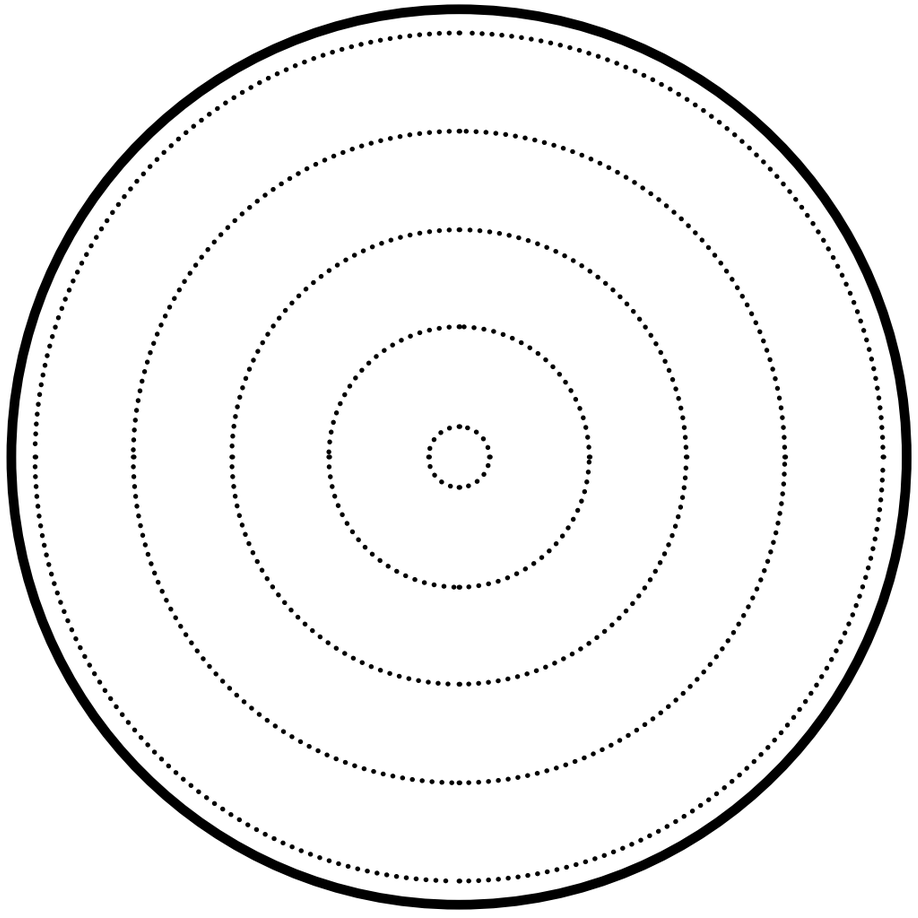


INTRODUCTION

THE BODY COLLECTED

■ Skeletons, organs, tissue and blood samples from newborn babies. There are large amounts of human material collected in hospitals, research institutes and museums. Both from the patients of the past, and from our own bodies.

The exhibition *The Body Collected* at Medical Museion charts how doctors and researchers have collected, preserved and stored this material to map and understand the human body and its diseases. And how the body has been used to generate medical knowledge. Layer by layer, the body has been laid bare and investigated: cut up during dissection, magnified under microscopes, and analysed biochemically. From historical collections of specimens to the blood samples of today, we and our predecessors have quite literally given of ourselves to discover what we now know.

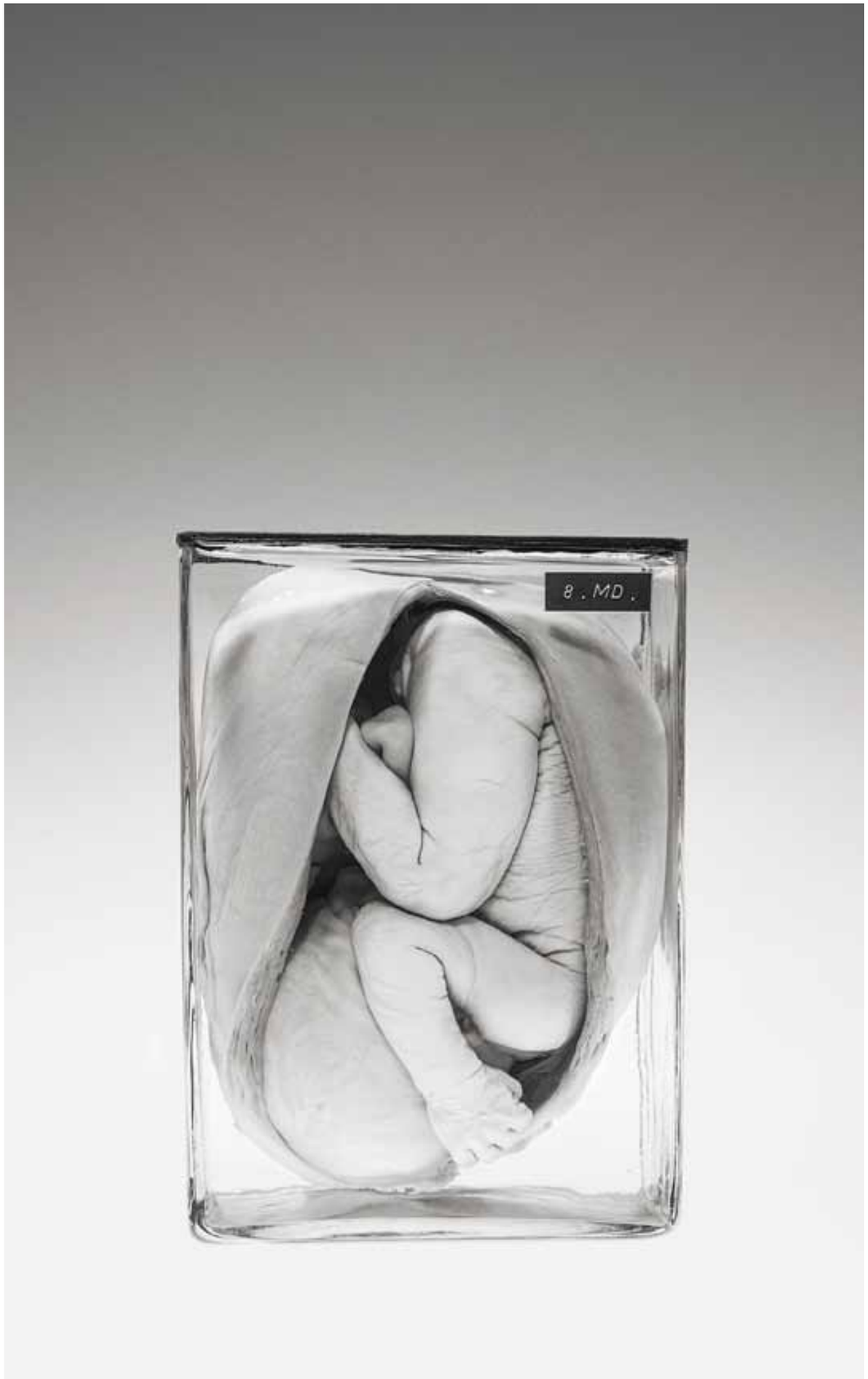
The exhibition is the fulfilment of a long-held wish to exhibit one of Europe's finest collections of human specimens. The material in it has been collected since the end of the 1700s, and comes from research collections of foetuses, skeletons, bones, organs and tissue samples - the collections generations of doctors and midwives have used to study human anatomy and disease.

The material exhibited also includes modern biomedicine, where the collection of human tissue continues to play a crucial role. Here samples of human tissue and blood provide the raw materials for understanding the body and developing new diagnostic methods and treatments. The vast majority of us have provided a tissue or blood sample that is now stored in a biobank.

The exhibition combines historical, anatomical collections with contemporary biomedicine, showing how the human body has provided the basis for medical breakthroughs from the early 1800s to today. The exhibition is both historical and scientific, which is reflected by the group of authors who have contributed to this exhibition catalogue: historians, doctors and researchers, all writing from the perspective of their respective fields.

The exhibition also explores existential and ethical issues about our relationship to our physical bodies. This is not an explicit theme, but something we are constantly aware of when looking at human material. The exhibition and this catalogue can provide a basis for discussing who we are, and the nature of our relationship to our bodies.

To understand the body is to understand our possibilities and limitations. The words 'Know Thyself' from the temple of the oracle of Delphi are displayed in many dissection rooms, making the idea that self-knowledge is the first step to all knowledge very physical. A key foundation for our knowledge of ourselves and the world surrounding us can be found by dissecting, investigating and understanding the human body ■



SCALE AS AN EXHIBITION PRINCIPLE

Karin Tybjerg • Historian of Science and Associate Professor

■ The main exhibition principle is simple, instantly graspable and captures essential features of the historical development of medicine. Objects in the exhibition are ordered according to scale, ranging from the whole body to its molecules: embryos, organs in jars, biopsies, slices of tissue, blood samples and DNA. The principle of scale draws on the materiality of the objects, but at the same time mirrors a shift in medical interest towards smaller and smaller units.

Before 1800 the whole body was the main unit of medical investigation, and disease was believed to be caused by an imbalance in the entire body. The whole body is present at the beginning of the exhibition in collections of foetuses, infants and skeletons. Although the body has been anatomized, we can recognise ourselves and the human form.

This perception changed with the development of large collections of anatomical and pathological specimens in the 19th century. Disease became linked to specific organs that could be excised. Disease was seen as a local phenomenon, identified with lesions on the organs. When we look at the specimens, we can recognise hands, feet, brains and hearts, but many of them appear as unidentifiable lumps of bodily matter.

The invention of the microscope made it possible to investigate structures of human tissue invisible to the naked eye. The building blocks of the body and symptoms of disease could now be investigated at a deeper level. This led to a new understanding of disease as abnormal changes in tissues and cells. But the decreasing scale did not stop there. Today the body is investigated at the molecular level on the basis of genes and biochemical traces in the blood.

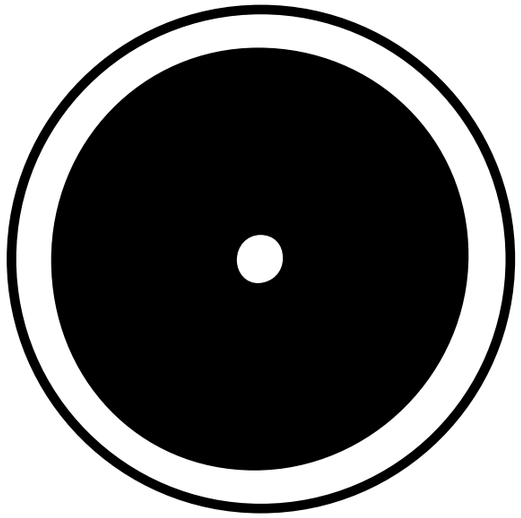
As visitors move through the exhibition, and the body parts become smaller and smaller, it is as if the human being disappears from medicine. We can relate to a foetus or a skeleton as individuals, but less so to a blood sample. The human body has not just been anatomised – it has been atomised. But at the very end of the exhibition we meet the individual again, in the DNA molecules of modern biomedicine. In the quest of medical science to find the fundamental building blocks of the body and disease, we rediscover the individual in the DNA molecules that comprise human genetic material.

But mapping the genome has not provided all the answers. The exhibition ends where medical science stands today. The smallest elements of the body did not hold the key, so both medical scientists and visitors to the exhibition have to retrace their steps through each level of the scale in an attempt to understand the human body at every level ■

FOETUS IN WOMB
An 8-month-old foetus in the womb, which has been cut open to reveal the foetus inside.

SCALE IN MEDICINE
The collected parts of the body are exhibited according to size, from the whole body to DNA molecules.

THE WHOLE BODY



In the collections of skeletons, infants and foetuses we find *the whole body*. Although they have often been dissected to investigate the details of their anatomy, they appear as individuals.

THE SAXTORPHIAN COLLECTION
Collection of normal, malformed and diseased foetuses and infants from the 19th and 20th centuries.

THE SAXTORPHIAN COLLECTION

Ion Meyer • Museum Conservator and Head of Collections

■ *The Body Collected* presents a major medical collection of foetuses and infants to the public for the first time in Denmark. These come from the Saxtorphian Collection, which was founded in 1787 by Matthias Saxtorph [1740-1800], professor at the Danish Maternity and Nursing Foundation. Obstetrics was a new field at the time, and Saxtorph needed a collection to understand foetal development and teach medical students and midwives.

The collection includes academic texts, medical instruments and specimens. The oldest books are from the 1500s, and today this library provides unique documentation of early developments in obstetrics. The instrument collection shows the development of forceps and the instruments used to destroy the foetus before birth, which could be necessary if a normal birth was impossible and the doctor had to try to save the mother's life. The specimen collection includes bone specimens like women's pelvises, and hundreds of wet specimens of foetuses and infants.

The Saxtorphian Collection was transferred to the Danish Maternity and Nursing Foundation in 1840, and moved to the new Rigshospital [Denmark´s national hospital] on its foundation in 1910. It gradually lost its relevance for research and teaching, and in 1992 became part of the collections of Medical Museion. The collection has been invaluable for generations of doctors and midwives, but is largely of historical interest today. Matthias Saxtorph was inspired by the ideals of the Enlightenment, whereby old dogmas and superstitions were to be combatted by knowledge. He refused to accept widely held superstitions, believing that there had to be a natural explanation for why some babies were born with serious congenital abnormalities. Knowledge about foetal development and the fact that the foetus can be struck by disease was seriously limited during the period. The collection represents an early but important step in understanding and treating the serious disorders that can develop during foetal development.

The Body Collected shows a large selection of the wet specimens of foetuses and infants that Matthias Saxtorph and his successors used to teach normal and abnormal foetal development. The specimens on display thus reflect contemporary needs for material for teaching and research – a focus the exhibition strives to retain. The historical practice documented by the collection has thus not been subject to present-day censorship.

Encountering the specimens offers us the opportunity to reflect on existential issues and also has an emotional impact. Visitors may react to the exhibition differently: with interest, curiosity and fascination, or with sadness or horror. Few will remain unaffected ■

CONJOINED TWINS
Twins joined at the chest.

“…you would be delighted to ponder the construction of the most perfect of all creatures, and take pleasure in considering the residence and instrument of the immortal soul — a dwelling which, because it corresponds admirably to the universe in many things, the ancients with good reason called ‘little world’.”

Andreas Vesalius, Anatomist and Doctor
De humani corporis fabrica
1543

NORMAL FOETUS WITH PLACENTA The foetuses in the Saxtorphian Collection were used in classes for midwives, among others. Here the development of a normal foetus was key, and the collection made the growth hidden inside the mother’s stomach visible. This was before technology like ultrasound made it possible to see the foetus. Although the foetus above is anatomically normal, categorising it as ‘normal’ appears paradoxical, since the baby was never born. Foetuses and infants are no longer preserved as specimens in Denmark, since parents are not permitted to donate the bodies of their children to science.

CHILD WITH UMBILICAL HERNIA

Gorm Greisen • Paediatrician and Professor

■ A fine, little person sits in a jar. On a shelf. A human being that with its fine features and hands greets us across the centuries. It is as if it is sleeping, but it is dead. So this is also the dead speaking to the living.

I am a paediatrician. I have specialised in working with newly born babies for most of my professional life. I have seen a lot of babies open their eyes after a birth that was difficult – or way too early – where I was called in, just in case. I have also often been called in when an ultrasound scan had revealed that the baby parents were expecting had a malformity.

The baby in the jar is malformed. The abdominal wall has not closed around the intestine as it should. The intestines and liver are inside a big balloon of membrane. In Latin, *omphalocele* – the severe kind of umbilical hernia.

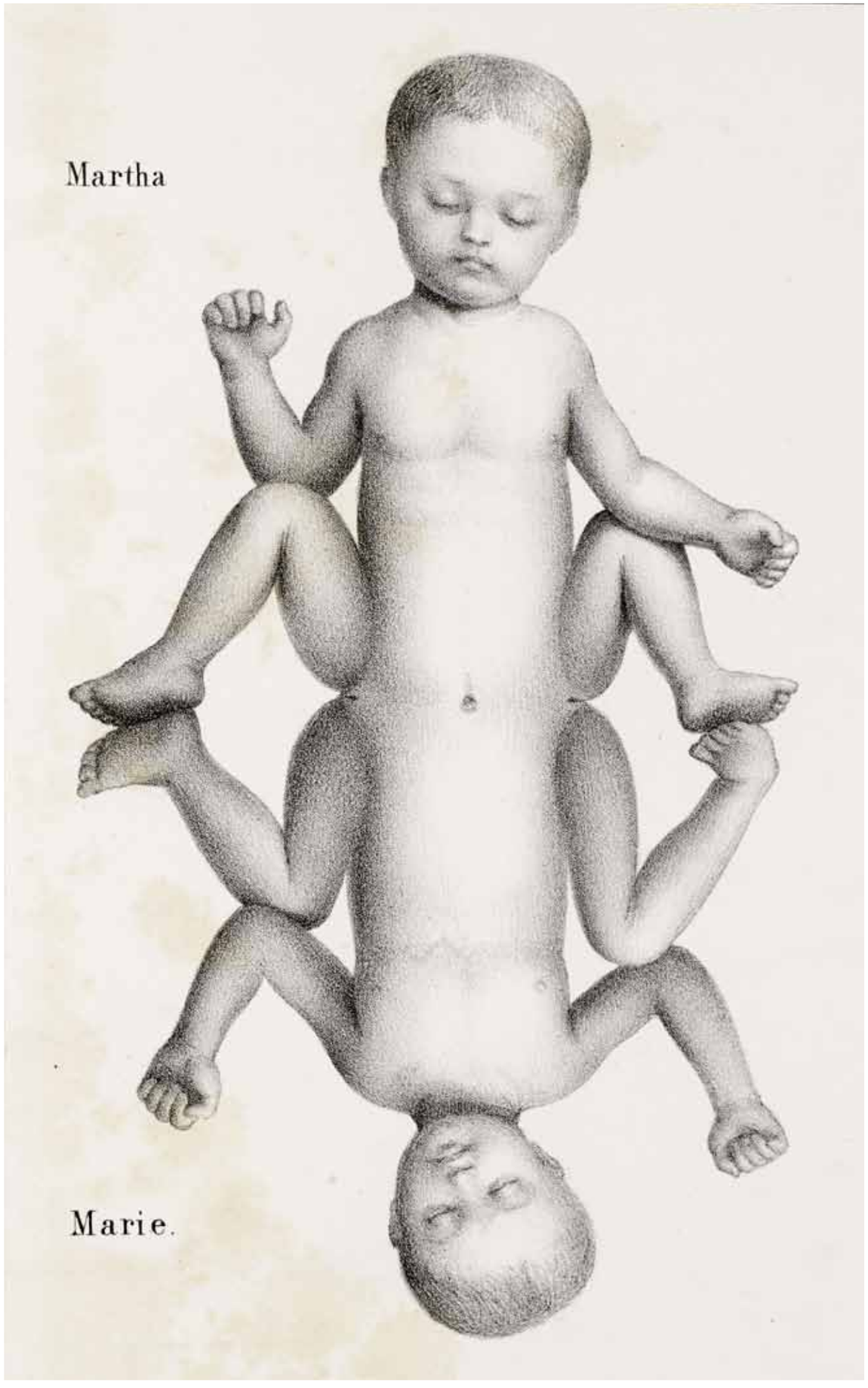
These days a surgeon is also on hand. Babies like these can be anaesthetised, operated on, and in many cases have a good life. If it is not possible to obtain good results by operating after birth, maybe in the future we will be able to operate before, then put the child back so it can continue to grow inside its mother´s womb.

The baby is squashed against the sides of the jar. And towards the bottom of the jar it is difficult to see what is going on. Does it have a totally malformed lower body, or is what we see part of the placenta? It would be tempting to lift the baby out of the liquid and gently take it apart. *Omphalocele* is often accompanied by other malformities, so it is important to know whether there are any others before operating. Maybe we could take a small sample and examine it under a microscope? Or do an MR scan? We could maybe also ask for a sequencing of the baby's genes?

This baby and its malformity/malformities are real. This is not an illustration. What we see is factual – a small part of reality. I see the malformity with the understanding my colleagues of the past have laboured to reach through their careful preservation and description of malformed babies. But we often do not know the cause. Maybe there were a range of causes and mechanisms. And this baby is hiding its history.

In the above I have written 'baby' rather than foetus. In the beginning it was a fertilised egg. In Denmark today most people are expecting a baby that is wanted and planned. So when the first ultrasound scan is done – just short of three months into the pregnancy – it is the heart of the parents' baby that you see beating. So it is no small thing if the scan reveals a malformity. The parents might choose an abortion, but they lose a child ■

NEWBORN WITH UMBILICAL HERNIA
Serious malformation and lack of development in the abdomen of the infant.



MARTHA AND MARIE

Carl E. Levy [1808-1865] • Obstetrician and Professor

■ In 1848 a pair of conjoined twins were born in Copenhagen. The parents, the father being a poor, apprentice chair-maker, could not manage to care for them, so they were transferred to the Danish Maternity and Nursing Foundation. Here they were nursed, observed and finally subject to a post-mortem examination. Three specimens were made from their bodies: their skeletons [p. 28], their organs [p. 29] and a taxidermy of their skin to preserve their physical form. Several years later, Professor Carl E. Levy published a comprehensive account of their lives and anatomy. The publication was delayed due to objections by the parents. Below are parts of Levy's account of the twins: their birth, life, death and afterlife. Due to his publication we know more about the twins than any other children in the collection.

"[*The birth*] *took place at the expected time, and according to the midwife ran according to course, so she had no idea of any problems before the head, shoulders and half the chest of the first child had been born. The abdomen seemed to meet some resistance in the mother's pelvis ... the contractions continued to be effective, and within minutes the head of the second child was in her hands. It can surely not have been without psychological interest to witness the first reactions of the shocked midwife and miserable parents at the sight of the extended body of an infant with a head at each end, whose cries and movements were an immediate sign of life and demand for love and care.*"

"*During the first four days of their life the babies seemed quite well ... but during the morning of April 7th Marie's face suddenly grew bluishly pale ... On April 9th Marie seemed a little less drowsy, moving her face and eyes regularly ... On April 11th Martha became slightly unsettled, and would not suckle as readily as before ...*"

"*The following night Martha had been very restless; Marie had cried a lot, although was able to swallow a little milk at regular intervals ... During the day Martha stopped suckling and swallowing, and like Marie seemed to collapse. The bluish skin colour spread during the final hours before death, extending some way along Martha's abdomen. At 6 pm they passed away quietly, without apparent pain: first Marie, then 2-3 minutes later Martha, exactly 10 days after their birth.*"

"[*Later*] *an anatomical investigation was made of the strange malformation, the results of which comprise the contents of the following pages.*"

Excerpts from *Two Live-Born Conjoined Twin Sisters*, 1857, pp. 7-14 ■

MARTHA AND MARIE
Print of the conjoined twins Martha and Marie from the obstetrician Carl E. Levy's thesis, 1857.

SKELETONS OF THE CONJOINED TWINS MARTHA AND MARIE
The skeletons are normal apart from the pelvises, which are joined.
It would probably be possible to separate them surgically today.
1848

INTERNAL ORGANS OF THE CONJOINED TWINS MARTHA AND MARIE
Organs from the chest and abdomen. Marie´s organs [below]
are reversed compared to normal anatomy.
1848

“Such malformities demonstrate, however, when several of the same species are compared, that nature in the essentials follows a certain order, a particular course and uniformity in all of them. So it becomes possible, by regularly collecting and describing the species occuring, to pursue them step by step and perhaps discover a natural order and certain laws for such bodily malformities.”

Matthias Saxtorph, Danish Obstetrician
‘Descriptions of two children on whom the covering of the pelvic region was missing’
Nye Samling af det Kongelige Danske Videnskabernes Selskabs Skrifter
1799

THE MERMAID Mermaid Syndrome or *sirenomelia* is a congenital abnormality where the legs have grown together to resemble a mermaid’s tail. In the past malformations were seen as unique wonders or curses. They were associated with supernatural beings, or explained by the mother having seen something horrifying during pregnancy. By collecting them, doctors like Matthias Saxtorph were able to categorise and diagnose them. The myth, however, lives on in the Latin name for the malformation: *sirenomelia*, literally ‘mermaid-limbed’.

WHO IS COLLECTED?

Morten Hillgaard Bülow • Historian of Medicine and Postdoc

■ A key question in the context of the medical collection of humans and parts of humans is not only *why* they have been collected, but also *who* has been collected. A question that is not just practical – which bodies are available – but also reflects the norms and worldviews of medical science during different historical periods. Since the medical point of departure has been to learn about health and disease, about the normal and the pathological, any collecting activity reflects what is understood as normal or 'abnormal' at a given juncture in time. Which bodies were seen as being beyond the norm? And who decided what should be collected?

The medical, historical collection therefore reflects norms and worldviews that change over time and that are part of broader European cultural history. The Saxtorphian Collection of foetuses and infants, for example, bears witness to a medical view of bodily variations in which the so-called abnormal was to be separated, studied and saved for posterity, and where the individual foetus becomes an example of a category rather than a human being to be buried like other dead people. In a contemporary context, the collections of similar specimens would not be legitimised, and most people would presumably find this kind of objectification of atypical bodies ethically questionable.

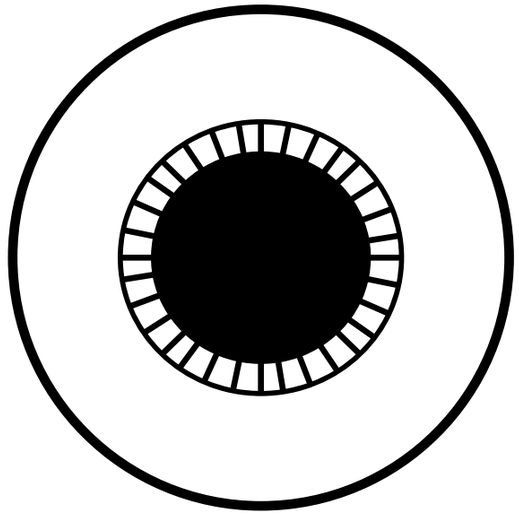
Another example is the skeleton where the cranium is labelled 'A Negro'. The skeleton belongs to a collection where the other anatomically normal skeletons are a Greenlandic woman and a child, and was probably used as an object of study in relation to the hierarchical theory of race prevalent at the time. The skeleton is of unknown origin, but has been collected in a historical context when colonialism and racism were an unquestioned part of the norms and worldview medicine operated under; a context in which it was relevant for Danish doctors to study human bodily material that was not pathological yet was still set apart from the white norm. The theories of race they operated under have since been discredited, and the term 'negro' is no longer used, since it has explicitly racist origins and belongs to Denmark´s past as a colonial power.

These examples represent only a fraction of a broader discussion about the role of medicine – and the specimens – in society during different periods. So if we ask who 'the body collected' was, the answer will be different at different stages of the exhibition. It is, however, still worth taking an extra look at how much bodily variation was necessary to be a collected body at different times in history. Which categories of class, race, age and gender play a role? And who is *not* in the collection? ■

SKELETON
The label 'En Neger' ['A Negro']
reveals the close relationship between
racial theory and the study of anatomy
in the past. Late 19th century.

SERIES OF NINE FOETAL SKELETONS
The development of the foetus, month by month. The row of skeletons gives the impression of growth, but consists of nine individual foetal skeletons. They are mounted as if they were grown children. They have strikingly large skulls and small jaws, since the jaw develops with the teeth after birth.

ORGANS AND BODY PARTS



Pathological and anatomical collections contain *organs* and *body parts* that have been excised from the dead to show where disease occurs in the body. The diseases can thereby be shown independently of the patients.

BONE COLLECTION DISPLAY
Skeletons and diseased bones from the University of Copenhagen. Predominantly 19th century.

UNDER THE SKIN

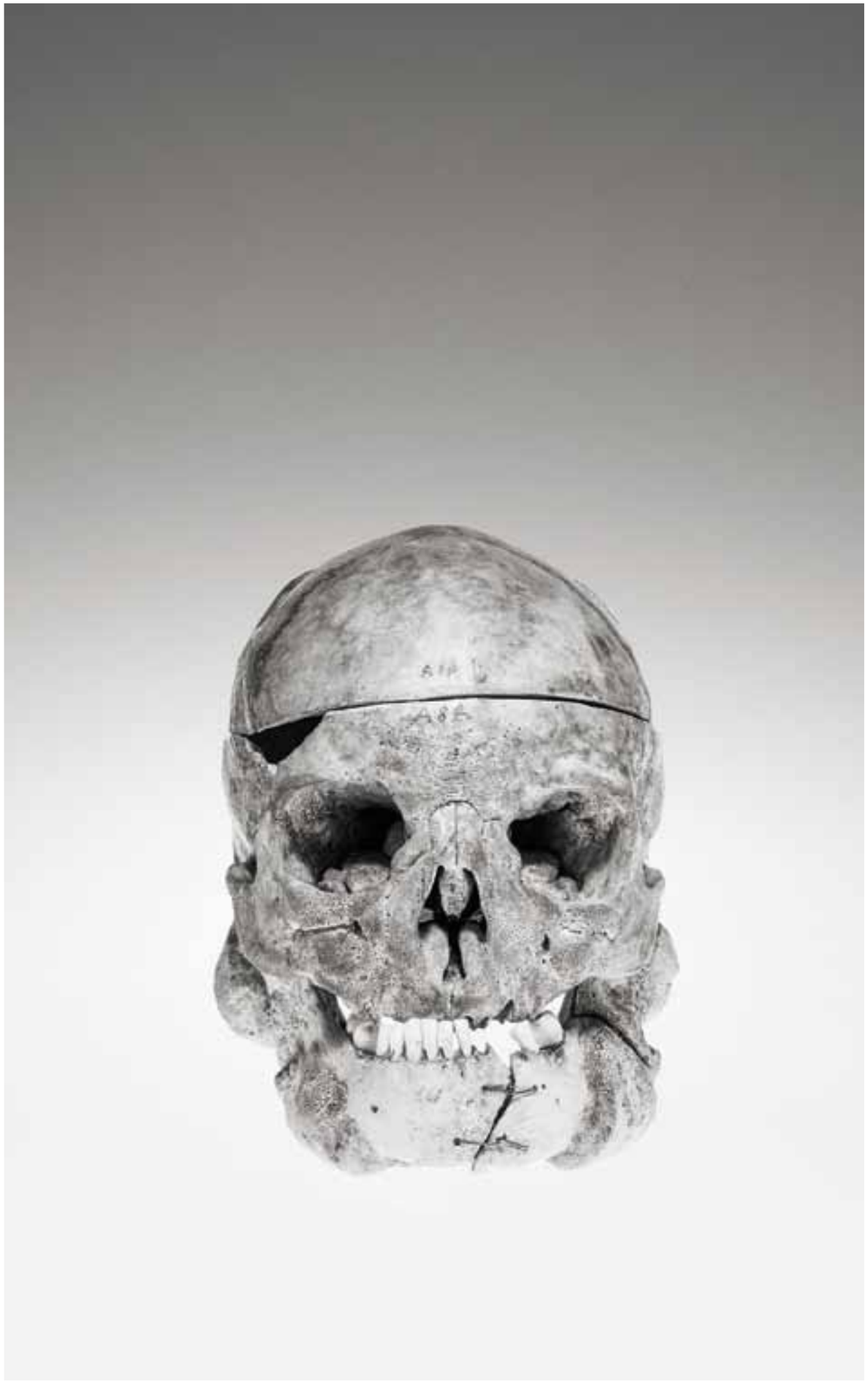
Adam Bencard • Historian of Medicine, Researcher and Museum Curator

■ *The Body Collected* tells an important and relevant story about the ways in which modern medical science has studied the body. But *The Body Collected* is also an exhibition that operates at a level beyond the historical and scientific. Due to the material it contains, it has a strongly existential dimension. It represents a direct and tangible confrontation with the physical body and the basic existential condition facing us all: that we are mortal creatures of flesh and blood and that we fluctuate between sickness and health.

This confrontation is initiated by our bodily perception of the specimens. When I stand before the malformed spinal columns in the display cases, it is difficult not to invest my own body in what I see. The bones resonate in my bones, and my inner body image twists in an attempt to match my shape to the shape before me. And in this twisting movement, this physical reaction to the body parts on display, I become present. My experience of the exhibition becomes more than the history of science and healthcare debates. The spinal columns are a kind of distorted mirror that make my own body more visible, more tangible. The experience provokes sensory reactions, thoughts, feelings and affective responses that are both highly individual and different, but at the same time touch a common human nerve.

The exhibition thus represents a meeting with the body and an invitation to reflect on its beauty, frailty, diversity and mortality, as well as the major efforts made to understand and treat it. In this way, the exhibition is a continuation of the long history of anatomy. For classical anatomists like Andreas Vesalius [1514-1564], the study of anatomy was not solely a question of adding a little more knowledge to the vast atlas of the human body. It was also an existential exercise, a practice based on the ancient maxim 'Know Thyself'. To observe, understand and study anatomy according to this tradition, is also to study human existence in a broader sense. Here the crooked spinal columns and the rest of the specimens contribute to the creation of an exhibition where we can, for better and for worse, learn more about ourselves and our bodily presence in life, sickness and death. In the exhibition we can meet ourselves right there, under the skin ■

TORSO
The spinal column has collapsed and the ribs have sunk into the pelvis. The cause is unknown.



BONES

Sven Erik Hansen • Medical Doctor

■ Bones consist of microscopic crystals embedded in a network of fibres and bone cells. The crystals account for two-thirds of the weight, and the fibres and cells the other third. The crystals consist of calcium hydroxyapatite - $Ca_{10}(PO_4)6(OH)_2$, - and the fibres of elongated, ductile collagen molecules. Bones specimens are made by boiling the body parts so the soft tissue can be easily removed. If the cartilage and ligaments are to be preserved, a more gentle technique of alternate soaking and drying is used.

Bones are fascinating, and preserved bones have had many uses. The skulls and crossbones has symbolised horror, death, poison or evil, whereas the bones of saints have been ascribed positive powers as relics. For artists, bones sketch the human form, and for archaeologists they provide evidence of life in the past. For collectors and scientists, bones are the part of the living organism that is easiest to preserve, and bones can, for example, reveal common features between animals and humans. Last but not least, bones with pathological changes can show doctors the traces disease leaves in the body, and skeletons are used in teaching.

Medical Museion´s bone specimens can be categorised as normal, archaeological and pathological. The archaeological bones come from graveyards and leper hospitals. The pathological bone specimens are primarily from two collections around 100-175 years old. One consists of c. 600 bone specimens from the pathological institute of Denmark´s national hospital Rigshospitalet, including bone fractures, chronic infections, rickets, cancer and congenital malformities. The other is the Saxtorphian Collection, which includes the skeletons of foetuses and the malformed pelvises of women who died in childbirth. Below some of the traces of disease that can be seen in the bones are described:

Leprosy attacks bones in the face, nasal cavity, upper jaw, shin, fingers and toes. Usually the sharp edges around the nasal cavity are eroded, and the cavity becomes an asymmetric hole. Irregular bone tissue can be deposited on the bones [see the photo to the left].

Syphilis can result in the deposit of newly formed bone tissue on the bones, alternating with irregular holes [p. 45]. Symptoms can also include expansion of the main arteries – aneurysms – which can lie close to the spinal column and create erosions on the spine [p. 46].

Abnormally enlarged craniums are due to lack of drainage in the fluid-filled cavities of the brain. The cavities grow, pushing against the brain tissue, which in turn pushes the cranium outwards [p. 45]. This can cause permanent brain damage.

Tuberculosis in the bones is usually located in the spinal column and causes malformities, especially crooked spines [p. 47]. Large joints and the fingers can also be affected ■

SKULL OF A LEPER
The infection has created deposits on the lower jaw and cheekbones, while the upper jaw has been eroded.

“Those who have dissected
or inspected many [bodies]
have at least learnt to doubt;
while others who are ignorant
of anatomy and do not take
the trouble to attend to it
are in no doubt at all.”

Giovanni Battista Morgagni, Italian Doctor and Anatomist
De sedibus, et causis morborum per anatomen indagatis
1761

HYDROCEPHALIC SKULL [top] Six-month-old infant. In order to hold the cranium together, the connective tissue has stretched to the point of transparency. **SYPHILIS** [middle] The infection has caused serious disintegration of the frontal bone, revealing the spongy bone tissue below. **BONE CANCER** [bottom] The action of the cancer cells has led to abnormal, crystal-like calcium deposits on the skull – also inside the eye socket.

RIBCAGE WITH ONE-SIDED PULMONARY TUBERCULOSIS [above] On the infected side the lung membrane [*pleura*] has thickened and shrunk, pulling the ribs together. **SECTION OF A SPINAL COLUMN** [opposite page, top] Indentations on the vertebrae where the spinal column has adjusted to an aortic aneurysm. Living bone tissue adapts. **PELVIS WITH RICKETS** [opposite page, bottom] Lack of vitamin D makes bones soft. Here the bones of the pelvis have been compressed by the weight of the body, making the pelvic aperture too small. This prevents normal birth.

THE LANDSCAPE OF DISEASE

Karin Tybjerg • Historian of Science and Associate Professor

■ Shelf after shelf of pathological specimens. Categorized and ordered like a three-dimensional atlas of everything that can go wrong with the body.

Large numbers of pathological collections were founded in the 18th century and expanded during the 19th century, when hospitals became more widespread. Here doctors could compare the courses of illnesses and – when patients died – the traces of disease in their bodies. Post-mortem examinations, during which organs were removed and stored, became standard. In this way, every self-respecting hospital and university built up a collection where diseased body parts could be studied at a safe distance from the commotion of the hospital ward.

The collections were used to categorise diseases. In some collections, diseased organs were ordered according to their location in the body: brains, hearts, kidneys, bones or other parts of the body. In other collections, they were ordered according to the kind of disease to show how cancer or tuberculosis, for example, looked in different parts of the body. Categorised and displayed, such collections can be compared to collections of butterflies or beetles on pins, arranged systematically to understand differences and similarities. The chaotic landscape of diseases was categorised just like species of animals and plants.

Pathological collections reflect a localised understanding of disease whereby the disease can be isolated to specific sites in the body. The damaged organs could be removed, and the source of the disease identified. The body could thus be understood as a machine in which every organ was a functional part, and in which disease was seen as a technical malfunction.

One of the most important purposes of these collections was teaching. Using the collected body parts, doctors and medical students could actually see what they tried physically to feel and hear when they touched organs externally – or when they listened to a patient´s breathing using the newly invented stethoscope. Using the collections it was possible to observe what might be hidden inside the body, granting the doctor an indirect way of looking inside it. If the patient did not survive, the body was dissected and the diagnosis checked. Were the symptoms and cause of the disease as expected? Was the doctor's diagnosis correct?

Collections thus accumulated clinical experience in material form. Medical students could learn from history by seeing these 'experiences' in jars alongside the accompanying account of symptoms. In this way the dead of the past could help in understanding diseases now and in the future ■

SECTION OF BRAIN WITH CANCER
At the bottom a dark grey area full of small cysts can be seen – a typical malignant brain tumour, 1933.

DISPLAY OF DISEASED ORGANS
Collection of diseased and injured organs
from the University of Copenhagen.
20th century.

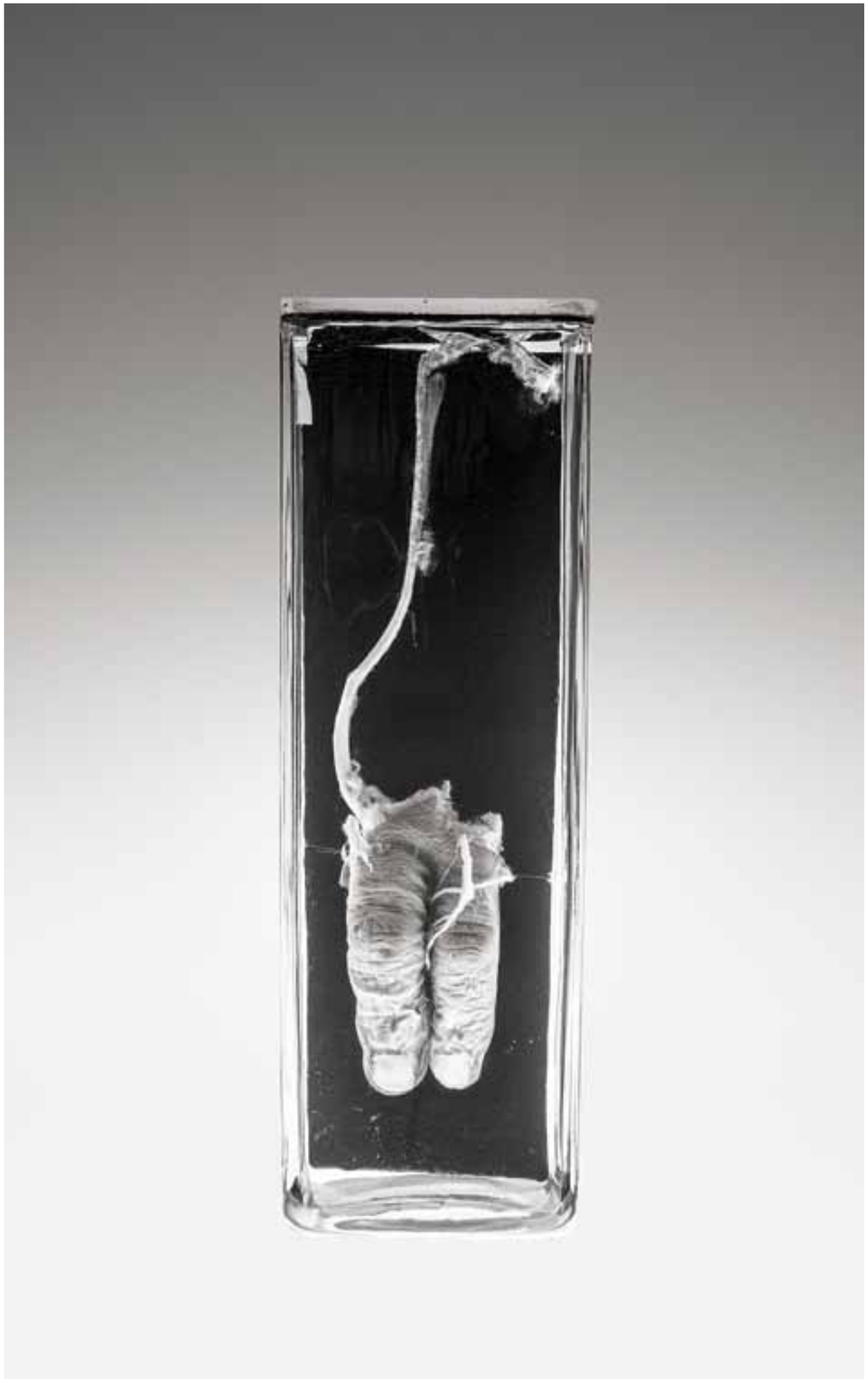
"… for twenty years, from morning to night, you have taken notes at patients' bedsides on affections of the heart, the lungs, and the gastric viscera, and all is confusion for you in the symptoms which, refusing to yield their mening, offer you a succession of incoherent phenomena. Open up a few corpses: you will dissipate at once the darkness…"

Marie François Xavier Bichat, French Anatomist and Pathologist
Anatomie générale appliquée à la physiologie et à médicine
1801

ENLARGED COLON A 13-year-old girl's colon heavily distended by constipation. The disease *megacolon* or Hirschsprung's disease is caused by a congenital lack of nerves in the intestine leading to an accumulation of faeces. The specimen shows the last part of the colon, where the problem is most acute. Most cases are diagnosed in infancy. The disease was first described by the Danish paediatrician Harald Hirschsprung [1830-1916]. During his lifetime children often met an early death due to constipation, but he predicted the possibility of the surgical treatment used today. 1900.

BRAIN AND SPINAL CORD WITH MENINGITIS
Child's brain with meningitis cut open. The infection can be seen as a white coating on the surface of the brain.

LUNGS WITH MALIGNANT TUMOURS
Whitish tumours can be seen on the surface. They have spread via the lymphatic system, 1930.



TWO SEVERED FINGERS
There are white shreds where the fingers have been torn off, as well as an 18 cm-long tendon, 1913.

THE FINGERS´ JOURNEY

Niels Chr. Bech Vilstrup • Historian and Museum Curator

■ The specimen jar contains the index and third finger of the left hand. They are covered in greasy oil, and the white shreds and long sinew indicate that they were ripped off the hand with some force. The label on the lid of the jar confirms that they were torn off. But how did the fingers of someone who was presumably a mechanic end up in the exhibition *The Body Collected*?

The index card for the specimen does not tell us much more, merely that the specimen is from 1913 and was donated to the Pathological-Anatomical Institute of the University of Copenhagen by Th. Rovsing in 1927. Professor Thorkild Rovsing died 14th January 1927, which is probably when the specimen was transferred to the University of Copenhagen.

Collections were often a by-product of a researcher's activities, and can provide documentation of the work they did. One such example is the wet specimens of rats and mice from the cancer research of Professor Fibiger, which earned him the Nobel Prize in Medicine in 1927. In other cases, collections are built up systematically because they were used in teaching and scientific work.

Most of the early anatomical collections at the University of Copenhagen were destroyed by fire in 1728 and 1807. In 1842 the schools of medicine and surgery were joined in a single faculty of medicine, and their collections also merged. In 1844 an independent pathological-anatomical collection was made at the University of Copenhagen. Initially it consisted primarily of bones, but microscopic specimens were later added.

In 1900 formalin replaced surgical spirit as a preservation fluid in Denmark, which resulted in a significant rise in the number of pathological-anatomical wet specimens. The lack of space at the institute became an increasingly pressing issue during the 1800s, and in 1910 the Pathological-Anatomical Institute, headed by Fibiger, moved together with the newly founded Department of Forensic Medicine into new premises with good study rooms close to the new national hospital Rigshospitalet. From 1910 the institute conducted all post-mortem examinations of patients who died during admission to the hospital, whereas operation specimens were examined by the assistants employed by each hospital department. In 1913 Thorkild Rovsing was professor of clinical surgery at Rigshospitalet, and the preserved fingers are probably from a patient who survived the operation and hospitalisation. The specimen became part of the museum section of the Pathological-Anatomical Institute´s collection without the standard, detailed information, which is presumably to be found in the medical file from 1913.

Since 1989 Medical Museion has regularly received wet specimens not considered relevant to study from the institute, including these dramatic fingers ■

DEATH HAS A CAUSE

Bente Vinge Pedersen • Historian and Museum Curator

■ The jar contains a section of a throat that has been dissected and mounted on a black plate so the upper oesophagus can be seen. The tongue points upwards. The oesophageal opening under the uvula is blocked by a piece of orange. The fluid the specimen is preserved in has made the piece of orange almost unidentifiable. Only its membranes remain visible as a white mesh, whereas the formerly orange flesh is almost transparent. There is a label on the lid of the jar with the words: 'Blockage of Aditus laryngis by orange segment. 1945'.

About the circumstances of this fatal accident, the forensic collection´s registrant tells us the following. An older woman, who reached the age of 61, has been paralysed for several years. She is eating an orange in the company of her husband, but suddenly starts to retch and cough and falls out of the chair she is sitting in. The woman´s husband tries to help her, but in vain. The post-mortem subsequently establishes the cause of death as asphyxiation due to swallowing an unchewed piece of orange.

The specimen belonged to the Museum of Forensic Medicine Museum under the University of Copenhagen´s Department of Forensic Medicine, which from 1910 was located on a road next to the national hospital Rigshospitalet in Copenhagen. It was collected during Professor Knud Sand´s [1887-1968] term of office, and was presumably used for teaching purposes. From 1930-1958 Sand published six editions of the textbook *Optegnelser til Retsmedicin* ['Notes on Forensic Medicine']. The book provides a systematic review of the discipline of forensic medicine, which in its essence is about about establishing the cause of unexpected deaths.

A certificate has to be issued for all deaths, and the cause of death has to be established. Knud Sand explains how the death certificate differentiates between *cause of death* and *manner of death*. Whereas according to Sand, the cause of death is "the factor directly causing death" – here asphyxiation by an orange segment – the manner of death refers to its circumstances. Is the death natural [defined by Sand as death from disease], murder, suicide, an accident, or due to an unidentified cause? If the manner of death is unknown, a post-mortem examination can probably establish if it is one of the four first. The woman´s death was an accident.

The goal of forensic medicine is to determine the cause and manner of death as accurately as possible through a systematic examination of the dead body during a post-mortem. Historically the boundary between the dead and apparently dead due to asphyxia has interested both doctors and non-specialists, especially in cases where the cause of death was linked to a blockage of the air passages where there were cases of the apparently deceased reviving or being resuscitated. This was sadly not the case here. The woman died from asphyxiation due to an internal obstruction of the windpipe ■

LARYNX FROM CHOKING VICTIM
Specimen from the collection of the Department of Forensic Medicine.
The entrance to the throat is blocked by a piece of orange. 1945.

“Pathological anatomy is a science whose aim is the knowledge of the visible alterations produced on the organs of the human body by the state of disease. The opening up of corpses is the means of acquiring this knowledge; but in order for it to become of direct use … it must be joined to observation of the symptoms …”

René Théophile Hyacinthe Laennec
French Doctor and Inventor of the Stethoscope
‘Anatomie Pathologique’, *Dictionnaire des Sciences Médicales*
1812-1822

TAPEWORM IN THE SPLEEN This specimen shows a tapeworm, also called *Echinococcus*, that has grown in someone´s spleen. The tapeworm is a parasite that spreads through faeces, and is common in countries with a lot of sheep farming. This specimen comes from Iceland, where the condition was common in the 19th century. The specimen, showing a very rare condition, was made in 1922, when effective treatment to prevent the spread of tapeworm larvae was implemented. Tapeworm has long since been eradicated in Iceland.

SECTIONS AND PATHS

Doctors learn about anatomy through dissection. To investigate anatomy, the intact body has to be destroyed. Each specimen can only show individual aspects of the structure of the body, not all of it. A *section* of an arm, or the *paths* of tendons

BODY DONATION

Jørgen Tranum-Jensen • Professor of Anatomy

■ Detailed and intimate knowledge of human anatomy is an essential qualification for almost the entire medical profession. The greatest historical breakthrough in exact knowledge about human anatomy came in 1543 with the publication of *De humani corporis fabrica,* based on the painstaking dissections of the deceased performed by Andreas Vesalius [1514-1564], who refused to believe handed-down accounts of anything he had not seen and verified with his own, critical eyes. This was also the approach of the Dane Niels Steensen [1638-1686], whose discoveries included the principle behind the mechanism that makes muscles contract. This discovery still holds true today, now with the addition of molecular details on how muscle fibres shorten during contraction.

We might think that the subsequent three-four hundred years of research based on dissections of the deceased had uncovered every inch of human anatomy. But this is not the case, since surgical techniques and diagnostic imaging [CT, MR and ultrasound] continue to become increasingly refined and capable of probing human anatomy with a degree of detail existing knowledge cannot match – including clarifying anatomical variations between people.

For medical students, dissection – where they work through the human body with their own hands – is crucial because it gives them a unique opportunity to become familiar with the three-dimensional location of the body's structures [muscles, organs, vessels and nerves]. Their observation skills are honed, and they witness the anatomical variations not shown in their textbooks, which only describe what anatomy looks like in the majority of cases. They realise that when penetrating the skin with their scalpel and scissors they have to be alert, because the structures they are exploring might be in a different place than in an anatomical atlas.

When specialising in surgery, it is crucial for new as well as experienced surgeons to be able to practise surgical interventions – young surgeons more simple operations, and experienced surgeons more advanced and new procedures – without worrying about harming a living human being. In anaesthesiology, the ultrasound-guided use of local anaesthetics and pain relief requires a highly detailed knowledge of anatomy and where the nerves are located in order to make the injection optimal. This is far from easy, and here too being able to practise injections on the deceased is key. A mere half millimetre can make all the difference between a successful and unsuccessful injection.

For researchers, being able to experiment on the dead makes it possible to explore and analyse in ways that would be impossible on the living. This applies, for example, to the locomotive apparatus [muscles, bones and joints].

The University of Copenhagen has a donation programme, which annually and gratefully receives the bodies of around 250 people who have donated their body to research and education. This helps, but is far from enough to meet all needs ■

DISSECTED FOOT
Specimen showing the location of the tendons of the foot.

"... no anatomist sees himself in a terrible slaughterhouse; under the influence of his scientific idea, he traces with joy a nerve fiber through stinking, rotten flesh, which for anyone else would provoke disgust and repulsion"

Claude Bernard, French Physiologist
Introduction à l'étude de la médicine expérimentale
1865

DISSECTED HAND The skin and connective tissues have been removed so the tendons can be studied. The hand is magnified due to the roundness of the jar. In general, when the face, hands or feet are visible in a specimen we are made very aware that it is part of a human being as well as a scientific object. Medical students also report that details like nail varnish and tattoos on the bodies they dissect remind them that the bodies once belonged to people – people who chose to donate their bodies to education and research.

DISSECTING KNOWLEDGE

Karin Tybjerg • Historian of Science and Associate Professor

■ Anatomical specimens do not only reveal what is inside the body, they also reveal our understanding of it.

What we learn by dissecting the body depends on how it is cut. When the inside of the body is exposed, we see it differently depending on how the incision is made. If the anatomist exposes the veins and nerves, he or she reveals connections and pathways in the body. This is clear in the cases of the dissected hand and foot [pp. 64 and 67]. If, on the other hand, a body part is cross-sectioned, we see where the muscles, nerves, veins and bones are placed in relation to each other. Knowledge is carved out when the body is dissected.

Normal anatomical collections show the anatomy of a healthy body. This is where medical students learn to navigate the body. By examining the anatomical structures of different 'cuts', the students learn to understand the body in sections, as well as becoming aware of its complex networks.

A well-prepared specimen takes a high level of skilled craftsmanship – uncovering and cleaning without removing the essentials, and accentuating what is most important. The art of dissection was developed by anatomists and surgeons, and the word surgery itself is based on the Latin *chirurgia* from the Greek *kheirourgia* meaning 'handiwork' [*kheir* 'hand' + *ergon* 'work']. Varnish, wax and colours are often used to accentuate and protect specimens. So when we look at preserved parts of the body, we are looking at a combination of the nature of the body and the technicians' craftsmanship or art. The British anatomist Charles Bell wrote in his guide to creating specimens that: "Injections [of wax] may be of service as a means of making the parts more beautiful and natural" [*System of Dissections*, 1798].

One of the oldest specimens in the collection of Medical Museion is a head from the early 1800s showing the muscles and veins of the face. It was probably made at the Royal Danish Academy of Surgery and used for teaching. The skin, hair and fat have been removed from the head, which was then dried and varnished. The brain, which decays fast, has been removed. To accentuate the veins of the face and prevent them from collapsing, they have been injected with a wax solution. They have then been painted to accentuate the veins and arteries.

A striking feature of the head are the eyelashes, which are still attached to the eyelids. Even though the rest of the varnished head might look like an anatomical model, the eyelashes remind us that the head once belonged to a human being ■

HUMAN HEAD
Dried head with wax-injected blood vessels.
Early 19th century.

THE LIQUID IN THE JARS

Ion Meyer • Museum Conservator and Head of Collections

■ The large displays in the exhibition are full of jars with preserved body parts. We see the jars with human specimens, but we hardly notice what there is most of – that all the specimens are stored in a liquid that is totally crucial to their preservation and how we see them.

The liquid has preserved the human material in its original form and prevented any natural decay. It has stopped the clock, and we cannot tell how old the specimens are. There would be no specimens without the liquid. It has preserved them and can continue to do so for years to come. It is also crucial for how the specimens are perceived. The liquid is transparent, enabling the individual significance and unique characteristics of each specimen to be seen from all angles. The liquid also creates a sense of movement when it reflects the light that penetrates the jar. Some specimens are mounted on a back panel, whereas others seem to float weightlessly in the liquid. This is possible if the density of the liquid is regulated to match that of the specimen. Each of us sees the specimens differently, and the visitor to the museum today sees them in other ways than the medical student in a clinical environment saw them generations ago.

When a specimen is prepared, the anatomist begins by excising the part of the body to be used. The part of the anatomy that is to become the specimen is then separated by cutting away and removing everything surrounding it. This takes time, an exhaustive knowledge of human anatomy, and a steady hand. When this stage of preparation is complete, the specimen is subject to a chemical process that stabilises the organic material. The specimen can now be placed in the jar of liquid.

Many different solutions have been used to preserve specimens. Those on display in *The Body Collected* used to be preserved in formaldehyde solutions. These were effective in preventing bacteria, fungal growth and other microorganisms. But formaldehyde fumes are a health hazard, so the fluid in all the specimens has been replaced. The new fluid is a modification of a formula developed in 1897 by the German pathologist J. C. Kaiserling [1869-1942]. It consists of demineralised water, glycerol and potassium acetate. It is not toxic for humans, but still preserves the specimens. It has a higher density than formaldehyde solution, which increases the risk of the body parts floating to the top of the jar. It has therefore been necessary to hold some of the specimens down with weights or to secure them with thread. Changing the liquid in the jars has been a demanding task requiring a lot of careful preparation, but the specimens can now be exhibited safely.

The clock is still stopped, and the specimens will be able to speak their wordless language in the future too ■

CHILD'S LEG WITH TUMOUR
At the cut by the hip joint there is a tumour about 3 cm in diameter.

AN ANATOMICAL ARTWORK

Ion Meyer • Museum Conservator and Head of Collections

■ The glass dome on the black wooden stand frames an old, anatomical specimen. But it is also a beautiful, anatomical artwork. The colours and delicate wax stems that run through the three-dimensional network that was once part of a human being's lungs accentuate its materiality and aesthetics. The specimen was made in the mid 1800s, but we have very little factual information about it.

The yellow wax is a cast of the respiratory tracts branching out into the lungs. The thick vessels are the bronchi, where inhaled air passes before reaching the smaller bronchioles and ending in the small pouches called alveoli. The red wax is a cast of the part of the vascular system where the blood has taken in oxygen, and the green wax shows the passage of deoxidised blood through the lungs.

In the close contact between the alveoli and the tiny blood vessels there is an exchange of oxygen (O_2) and carbon dioxide (CO_2). Oxygen from the inhaled air passes through the walls of the alveoli to the small blood vessels, and the surplus carbon dioxide of deoxydised blood is transported in the opposite direction. The oxygenated blood immediately continues its vital journey to the cells of the body, and the carbon dioxide is led back through the respiratory system and exhaled.

It requires a lot of experience and technical skill to make a specimen of this size and quality. When the heated, liquid wax is injected into the vessels the pressure has to be high enough to fill all the vessels - even the smallest - but not so high that the vessels split and the wax escapes. When the wax has cooled and hardened, the tissue surrounding it is removed by what is called maceration, in this case using chemicals or simple decomposition. The process of decomposing the tissue surrounding a cast is called corrosion, and the specimen is therefore called a corrosion cast.

The delicate wax casts break easily and are very difficult to stabilise and preserve. Most wax specimens have perished over time, and despite being damaged this is the best preserved specimen of its kind in the collections of Medical Museion.

Numerous techniques and materials have been used to inject into body parts like blood vessels and respiratory passages, and the results have been crucial for understanding our anatomy and for research into how our organs function. This anatomically correct specimen has been studied by medical students. Today it is part of the history of anatomy, but it is also a beautiful and fascinating exhibit. ■

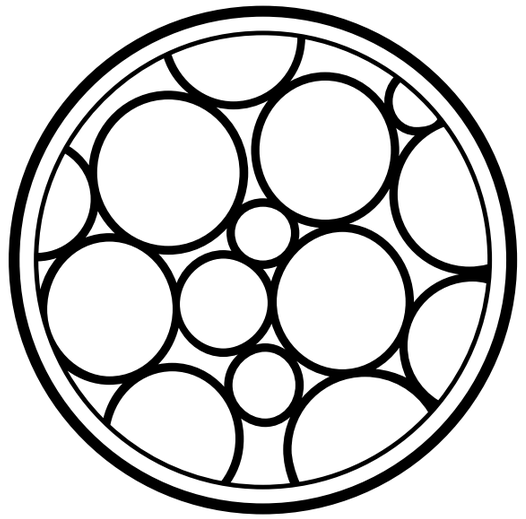
CAST OF VESSELS IN THE LUNGS
Wax is injected into the respiratory passages. Then the surrounding tissue is removed chemically or by decomposition. Mid 19th century.

“To succeed in making a good anatomical preparation, much patience, neatness of hand, knowledge of the subject illustrated, and some artistic talent are required”

William Henry Flower, British Anatomist and Surgeon
‘Museum Specimens for Teaching Purposes’, *Nature*
1876

BRAIN SECTION Embedded in plastic. When a neuropathologist – a specialist in brain disease – investigates the brain of the deceased, it is cut into slices to analyse the structure and size of elements like the brain cavities. The section above was used in teaching to demonstrate what to look for, 1950s.

TISSUE AND CELLS



The body consists of different kinds of *tissue* that in turn consists of *cells*. From the mid 19th century interest in the smallest parts of the body increased, and with increasingly advanced microscopes it became possible to see more and more of structures that cannot be seen with the naked eye.

THE BODY EMBEDDED

Malthe Boye Bjerregaard • Historian and Museum Interpreter

■ Thousands of small, square blocks fill this black cardboard box, each of them meticulously numbered and sorted in cassettes. Each block contains a human tissue sample [biopsy] embedded in paraffin wax. If the block is held up to the light, the sample becomes visible in shades of brown and yellow. But where in the body the samples derive from cannot be seen with the naked eye. The cardboard box contains a total of 1,129 tissue samples from Frederiksberg Hospital. They were all taken in 1956 during the diagnosis or post-mortem examination of patients, for example to determine whether a growth was malignant or benign.

The paraffin was used to stabilise and preserve the tissue sample, which could subsequently be cut into 0.005 mm thick slices and analysed under the microscope. Performing a biopsy can be a major operation or just a painful pinprick, but all biopsies can be performed on living patients. A sample that is only 0.5 cm^3 can reveal a landscape of cells under the microscope – the microscopic anatomy of the human body. The sheer quantity of samples is evidence of how easy they were to remove. Using the paraffin-wax embedded tissue and a microscope, the doctor could then study the body's battle against disease as it took place. The box and its contents therefore represent an important development in medical science's approach to the body: people could now survive being collected.

The many collected tissue samples were subsequently stored so doctors could double-check the diagnosis. Hospitals stored them on shelves where they were easily identified because their numbers corresponded to the number on the patient's case notes. The national hospital of Denmark, Rigshospitalet, for example, has stored all their paraffin blocks with samples since it opened in 1910. This represents a huge archive of bodies. Each cassette contains hundreds of human lives captured in a snapshot of their disease. They are also valuable research material for doctors to compare the diagnoses of the past with a patient's subsequent case history, or study material that is difficult to access today, such as samples from children.

Collections of tissue samples in hospitals can in this way be seen as the predecessors of modern biobanks. The sample and diagnosis are not viewed in isolation, but can be linked to the patient's case notes and Social Security Number ■

BOXED PARAFFIN BLOCKS
Collection of tissue samples embedded in paraffin. Used for diagnosis at Frederiksberg Hospital, 1956.

“Omnis cellula
e cellula”

All cells [come] from cells

Rudolf Ludwig Carl Virchow
German Doctor, Pathologist, Anthropologist and Politician,
‘Cellular-Pathologie’, *Archiv für pathologische Anatomie und Physiologie und für klinische Medicin*
1855

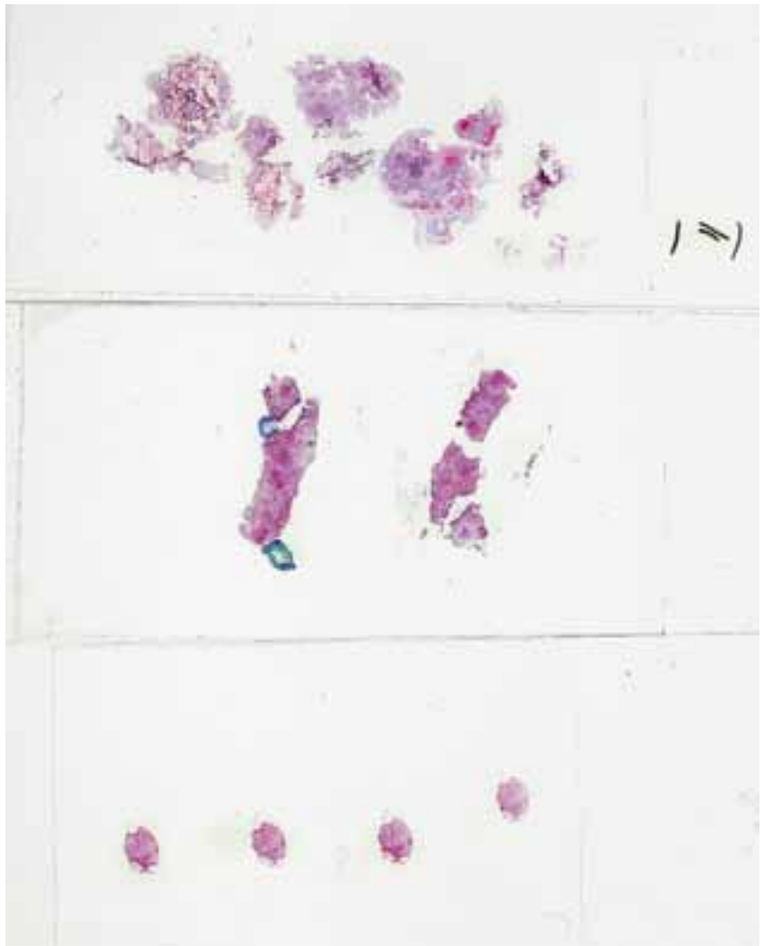
MICROSCOPE SLIDE FOR TEACHING
Section of the kidney of a 1 year old child.
1870-1900

MICROSCOPE SLIDE FOR TEACHING [above] Sections of the kidney of a 19-week-old foetus. The thin slices of tissue make it possible to study structures in detail, 1870-1900. **DISPLAY WITH MICROSCOPE SLIDES** [opposite page].

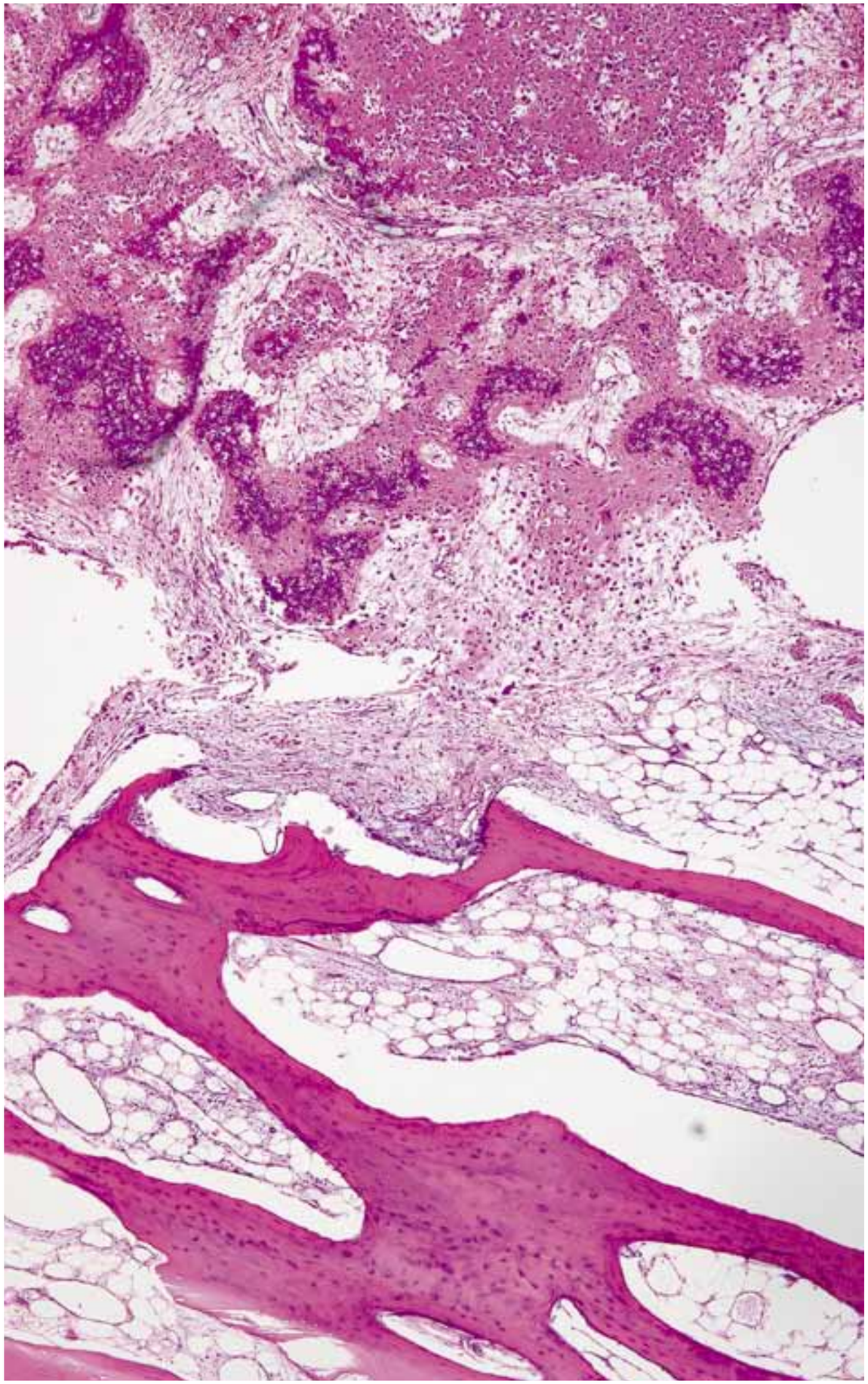
"As if nature had determined to hide from our eyes the marvelous structure of its organization, the cell, the mysterious protagonist of life, is hidden obstinately in the double invisibility of smallness and homogeneity. … The histologist can advance in the knowledge of the tissues only by impregnating or tinting them selectively with various hues which are capable of making the cells stand out energetically … transformed into a flock of painted butterflies."

Santiago Ramón y Cajal
Spanish Doctor and Nobel Prize Laureate in Physiology
Recuerdos de mi vida
1923

MICROSCOPE SLIDES FOR TEACHING
Made by staff at the University of Copenhagen's Institute of Anatomy.
1870-1900



TISSUE SECTIONS [above] Tissue sections made for teaching in pathological anatomy, 1957-1961.
ARCHIVE OF MICROSCOPE SLIDES [opposite page] Slides of tissue are archived and retrieved if a diagnosis needs checking or a patient is readmitted, 1975-1976.



RECOGNISING THE ABNORMAL

Erik Clasen-Linde • Pathologist and Consultant Physician

Interview by Malthe Boye Bjerregaard

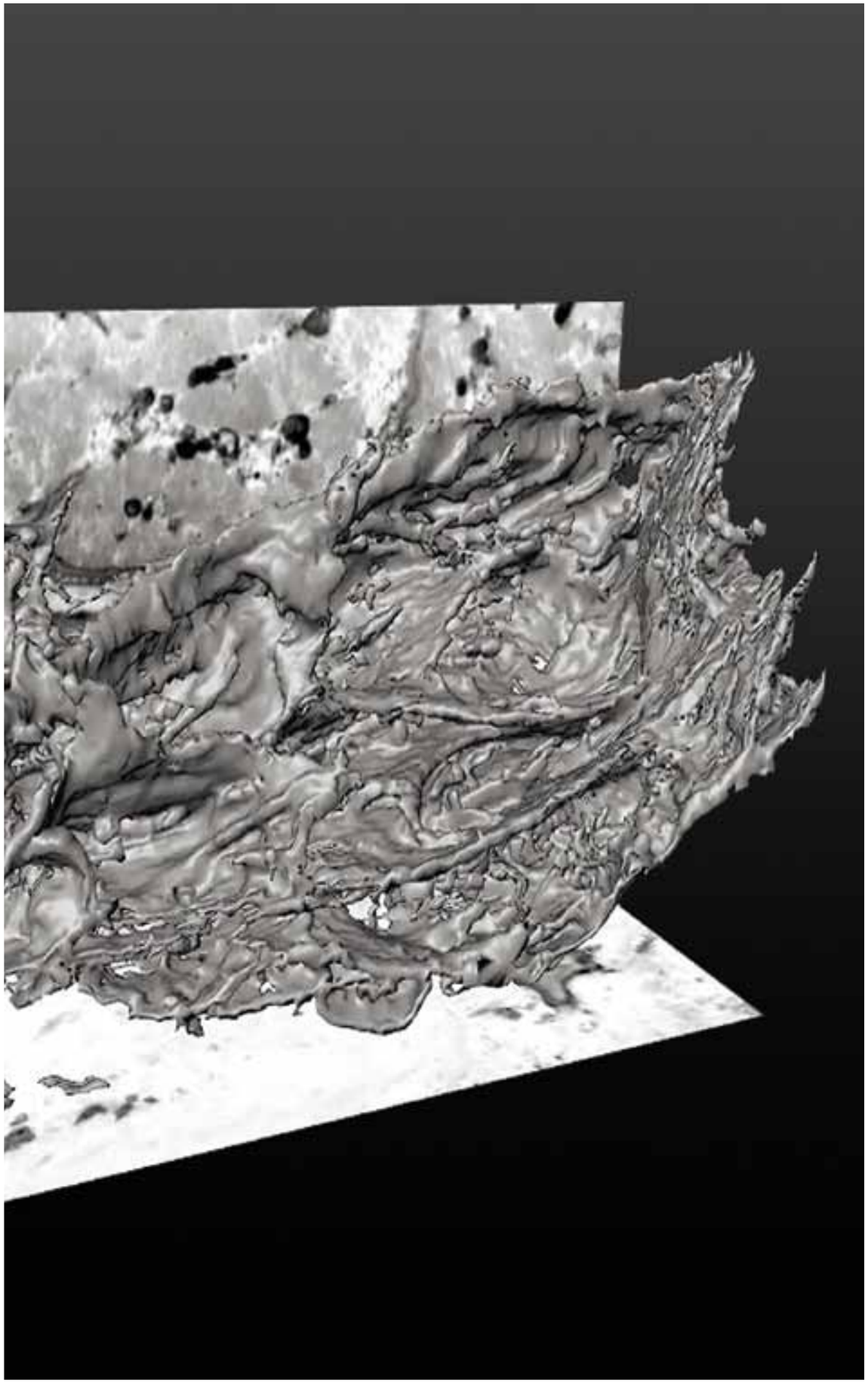
■ "It´s all based on what normal tissue looks like and how the body reacts to different diseases," according to Erik Clasen-Linde, consultant physician at the Department of Pathology at Denmark´s national hospital Rigshospitalet. Clasen-Linde is a specialist in the microscopy of diseases relating to bone marrow and the lymphatic system. But he never meets the patients, seeing only their case notes and tissue samples on microscope slides. The diagnoses of more than 25 patients are confirmed or disconfirmed every day: "By the afternoon my desk is full of glass splinters from the corner of slides getting chipped. We have to work fast."

Clasen-Linde places a slide from the exhibition under his microscope. We have cheated a little, because the slide comes from a teaching collection so we already know the diagnosis: bone cancer [*osteosarcoma*]. He begins by looking at the sample at a low level of magnification to gain an overview. The tissue is dyed shocking pink to make the cells visible. The first thing that is visible is the normal bone tissue, which looks like microscopic columns [*trabeculae*] sporadically separated by the white pockets of fatty tissue. "My job is first and foremost pattern recognition. I compare everything I see under the microscope with my own mental image of normal tissue."

Clasen-Linde then increases the level of magnification and moves the focus of the microscope to the left. Here everything looks completely different. Red spots in the tissue indicate newly formed bone tissue, which is pressed between endless closely packed cells with enlarged nuclei. Normal bone tissue only has a few cells, but here the architecture of the tissue has completely broken down – a clear sign of a malignant bone tumour. All these aberrations are described in detail in the case notes that the doctor treating the patient uses in the subsequent course of treatment. The description is often consulted again if the patient is readmitted.

The many slides and glass fragments on Clasens-Linde´s desk are probably about to be replaced by digital images. Although digital imaging poses a challenge, because pathologists do not only look at a two-dimensional image under the microscope. The cells overlap, and Clasen-Linde focuses up and down through the different layers. To achieve the same effect in a digital image it has to be scanned in several layers, which can result in unmanageably large digital files. Clasen-Linde is prepared for the future, but not without his reservations: "It´s difficult, because we have a very personal relationship to our microscopes. I know instantly if someone else has used mine"■

TISSUE SECTION WITH BONE CANCER
At the bottom of the image the structure of healthy cells is seen, and at the top the disintegrated structure of the diseased bone, 1970s.



3D ELECTRON MICROSCOPY OF CELLS

Klaus Qvortrup • Medical Doctor and Professor

■ Electrons have a very short wavelength – more than 100,000 times shorter than visible light. An electron microscope therefore makes it possible to observe details at a far higher level of magnification than a light-optical microscope, making it possible to investigate the ultrastructure of individual cells.

The high degree of detail means that the tissue to be investigated must be as well preserved as possible. If active cells do not have enough oxygen - even for a few minutes - the cells die and start to decompose. Samples of human tissue for electron microscopy are therefore not suitable after death has occurred – they must come from a biopsy of living cells.

During *Transmission Electron Microscopy* [*TEM*], electrons pass through a very fine section of tissue. To be able to cut such an ultra-thin section, a very small [1 mm^3] block of tissue is embedded in plastic resin, after which an ultramicrotome cutting machine can cut sections 50 nm [0.000050 mm] thin. The ultra-thin section can then be examined and images of the tissue recorded. A *TEM* image can, however, only provide information about the content of the limited depth of the section.

Details frequently emerge where it is necessary to know how a specific structure in a cell continues. Using *TEM*, another 50 nm has to be cut from the block of tissue in which the same cell can be located and the continuation of it observed. The investigation can be continued section by section until an overall picture of how the structure looks in depth – i.e. a 3D image of the cell's contents – emerges.

An alternative to examining the thin sections is investigating the surface of the tissue in the plastic block using a *Scanning Electron Microscope* [*SEM*]. Here an electronic beam scans the surface, and the signal is recorded by a detector. Instead of transmitting electrons through a thin section, the entire surface of the block of tissue is now investigated. The images look identical to those recorded by a *TEM*.

The scanning electron microscope can be equipped with an ion-beam generator [*FIB SEM – Focused Ion Beam Scanning Electron Microscope*]. The ion beam can 'shave' layers of the surface to expose the content of the cells further down the block of tissue. One of the advantages of using this method is that as little as 10 nm of the block can be shaved, a far thinner section than can be cut using a *TEM*. The ion beam and microscope are controlled by a computer, which automatically controls the cutting of the section and the recording of the newly exposed surface. Accordingly, thousands of images can be recorded consecutively and subsequently merged in a highly detailed 3D reconstruction of the investigated field ■

MUSCULOTENDINOUS JUNCTION, 3D
The image is created from c. 580 images of cross sections taken at 0,00001 mm intervals. The level of image pixilation sets the limits for what we currently know. 2014.

HELA AND HENRIETTA LACKS

Malthe Boye Bjerregaard • Historian and Museum Interpreter

■ They might not look like much, the four thin slides. At first glance they look almost as if there is nothing on them. We can just make out something that could be mistaken for greasy fingerprints. But as we look closer, a number of clear, liquid-like circles appear on each slide. They are kept in place by a cover slip glued onto the slide using clear nail varnish. Each circle contains cells grown in a laboratory for scientific experiments. These unimpressive circles might not seem historically significant, were it not for the four letters on the labels: HeLa. The cells on the slides are the descendants of a line of cells that was one of the most important medical breakthroughs of the 20th century: the first human cells to be kept alive in a laboratory. HeLa is also inextricably linked to a particular individual – Henrietta Lacks – and her illness.

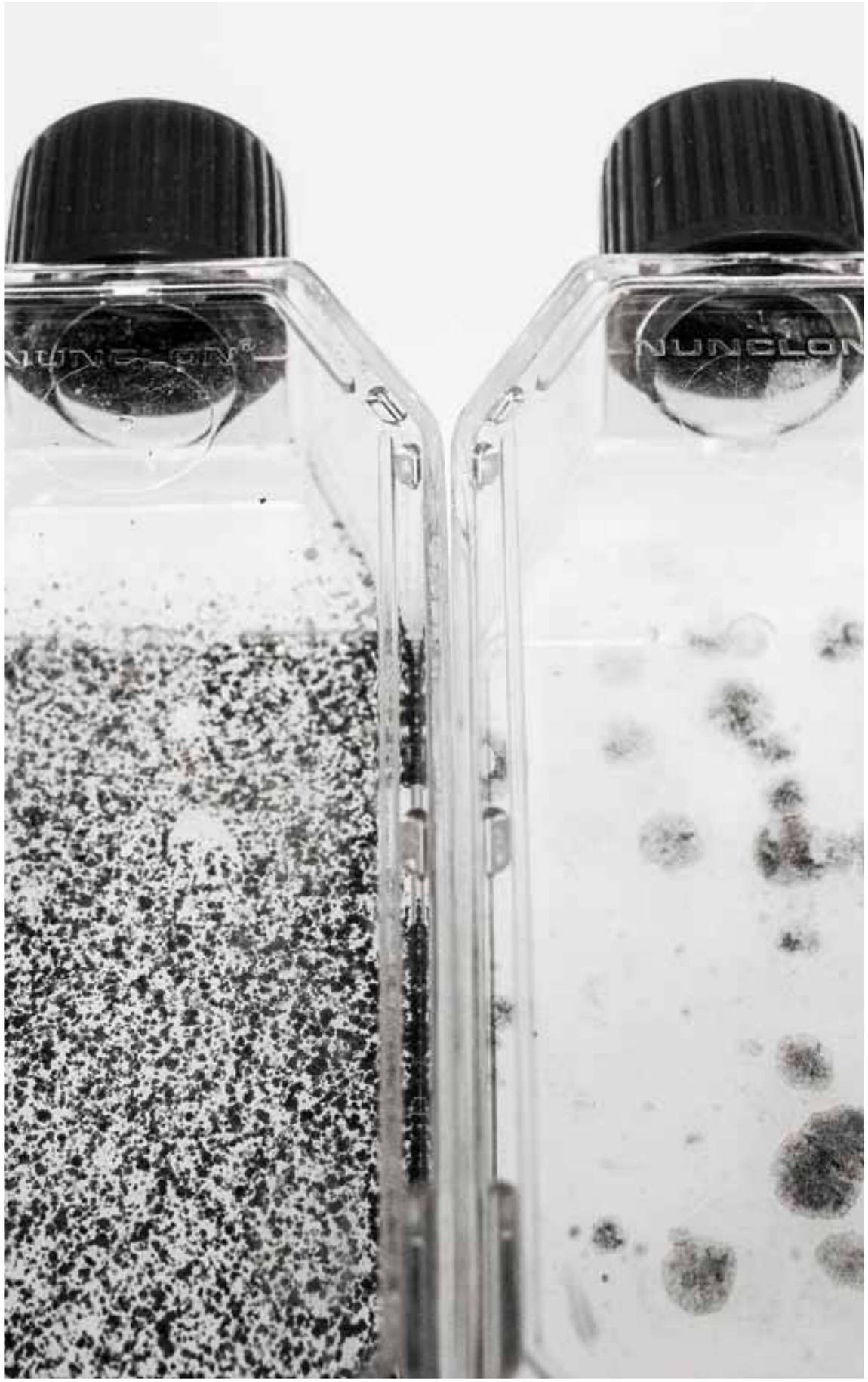
Henrietta Lacks was born in the state of Virginia, USA in 1920 and worked on a tobacco farm. She had her first child when she was 14 with her cousin, who she later married. In 1951 Henrietta Lacks went to Johns Hopkins Hospital in Baltimore because she had felt a lump in her abdomen. The drive was more than 30 km, because not all hospitals would treat African-American patients. She was diagnosed with cervical cancer and received strong radiation treatment, but it was unable to stop the cancer. She died at the age of 31, and was survived by four children.

Before she died, however, her surgeon took a biopsy of the cancer tumour – something done without her knowledge. The tissue sample was sent to the laboratory of the researcher George Gey, who had been trying to cultivate human cells for 30 years. Henrietta Lacks´ cells were the breakthrough. Within just 24 hours the cancer cells in the test tube had doubled – and they did not stop growing. George Gey had suddenly found the perfect human miniature laboratory animal.

Today HeLa is the most frequently used cell line, and it has been crucial in medical advancements like the development of the Polio vaccine, cancer treatments, cloning, and the mapping of chromosomes and genes. Henrietta Lacks' cancer created an apparently immortal cell line, which would later make her name immortal too. But at the same time her story was also the forerunner of one of the most central dilemmas in medical ethics: who owns our tissue?

Lacks´ family were not informed that her cells were in use in laboratories worldwide until the 1970s, and even then only because researchers were interested in the genetics of the cells. The family´s claims of economic compensation and acknowledgement were initially rejected, but in 2013 they were granted a say in how the genome sequencing data of the HeLa line was used ■

HELA CELLS
The cells have been treated with fluorescent stain and fixated with clear nail varnish. The cells descend from Henrietta Lacks´ cancer tumour – hence the name HeLa. 2014.



CELL CULTURES AND CANCER TREATMENT

Anne E. Lykkesfeldt • Biochemist, Group Leader at Danish Cancer Society

■ It is possible to cultivate breast cancer cells in plastic flasks in what we call a cell culture. Cancer cells can be cultivated in large numbers, and using the methods of molecular biology we can investigate which molecules control the growth of the cancer cells. Once we have identified the growth-stimulating molecules used by the cancer cells, we can direct treatment at blocking them. One of the main advantages of cell cultures is that many different treatments – and combinations of treatments – can be tested to find one that kills all the cancer cells.

Resistant breast cancer is a particular challenge. For some patients the treatment only works for a while, after which resistant cancer cells emerge. To find a treatment for resistant cancer cells, we treated cancer cells grown in cell culture with the same drugs that the patients are given. In these cell cultures we could see that cell growth was arrested and that most of the cells died. However, a small number of cells survived and emerged to form small colonies as shown in the photograph on the opposite page where the colonies are stained. These resistant colonies of cancer cells can be transferred to new plastic flasks and cultivated in large numbers so we can investigate their molecular composition and clarify which molecules control their growth. After this, drugs designed to block growth-stimulating molecules can be tested.

How can the cell culture be used in treatment? To ensure that the cells in the culture flasks mirror what is happening in the patients´ tumours, we can test whether the growth signals that control the growth of the cell cultures are also active in the cancer tumour. Here we use frozen or paraffin-embedded tissue from the patients´ tumours, and where possible also tissue from any metastases. It is therefore extremely important to take samples from the tumours and preferably blood samples too, which are stored in a tumour bank. Using this material from patients we can, for example, measure the level of the molecules presumed to control the growth of the cancer cells that are resistant to a specific type of treatment. After that we can investigate how the cancer has developed in the patients. If we discover that patients with tumours with a high level of the molecules we presume to be important for the growth of resistant cancer cells relapse earlier on the treatment, our model system mimics the patient´s cancer. The results of the targeted treatment experiments conducted in the model system can then provide a basis for new forms of treatment for patients with breast cancer ■

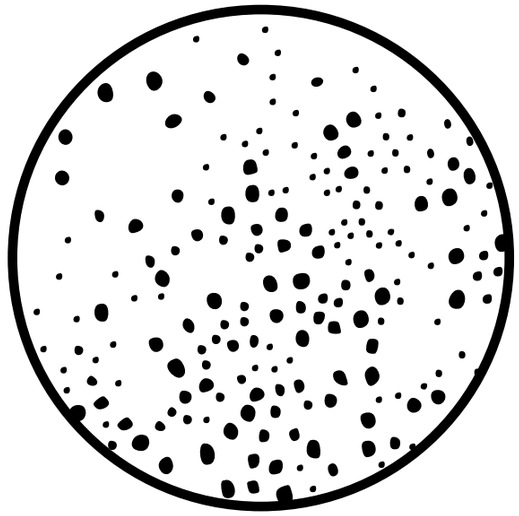
CELL CULTURES IN FLASKS
These flasks contain breast cancer cells from research at Danish Cancer Society Research Center. The cells to the left are untreated. The cells to the right have been treated with an antihormone. 1994.

“I dare say that you think that if a piece of your flesh was cut off by a surgeon it would be dead as soon as it parted from your body. But as a matter of fact this is not the case. In recent years science has shown that not only does animal and human flesh – or tissue to use its scientific name – remain alive for quite a long time after death, but that in some cases it may actually be made to go on living and growing apart from the body for months or even years.”

Honor Bridget Fell, British Scientist
The Life of a Cell, BBC Talk
1930

TOOTH CELLS The research is aimed at discovering whether a specific kind of stem cell – which can develop into bones, cartilage, muscle or fat – can form colonies. The cells are cultivated in petri dishes for 12 days, then treated chemically and stained to make them visible. The number of colonies is then counted. Growing cell cultures in modern laboratories is a form of high maintenance gardening. The cells continually need heat, nutrition and new dishes or flasks to grow in once they grow out of the old ones. 2014.

BLOOD AND MOLECULES



The *blood* transports signals, nourishment, oxygen and waste products around the body – the traces of healthy and diseased processes. The blood and its *molecules* can therefore be used to diagnose diseases – sometimes even before they break out.

FROZEN COLLECTIONS

Karin Tybjerg • Historian of Science and Associate Professor

■ At first glance a modern biobank in the 21st century looks completely different from a collection in a 19th century medical museum. The large freezers filled with small samples of blood or tissue do not look like the display cases of foetuses or diseased body parts in jars. Their names also indicate differences. We connect a *museum* with the past, as an institution that collects and stores old things. A *bank*, on the other hand, takes care of present-day valuables and invests with a view to future returns.

They are, however, not as dissimilar as we might think. The old collections of body parts helped doctors in the past diagnose disease. The doctor could compare a patient's symptoms with previous case histories. And he could compare what he felt on the patient's body with the body parts he had studied in the collection. If they matched, the diagnosis could be the same.

Biobanks offer the same possibilities, just with new biochemical and genetic tools. The researchers can compare biochemical compounds or genetic sequences in the collected samples with those of current patients. This gives the doctor new diagnostic tools. The process is still the same: we compare the symptoms, bodies and diagnoses of the present and the past. The difference is that in the 19th century people were not diagnosed until the disease was advanced and death often near, whereas today we try to diagnose at an earlier stage – maybe even before the disease breaks out.

The most valuable collections in biobanks are often the oldest, because we know what happened to the patients. We know their life history, how their illness progressed, and how they died. Which is why these collections provide the best way to trace connections between the components of the blood, diseases and causes of death. Just like the old collections in medical museums, biobanks draw on knowledge from the past.

Collecting and storing the human body is a key means of generating medical knowledge – now as in the past. In pathological collections the causes of disease were found in the damage done to organs, whereas modern biobanks look for new biomedical ways to detect the state of the body. Biobanks can be seen as collections of bodily material for our age. They are a kind of medical museum for very small parts of the body. Both the biobank and museum collect the patients of the past to answer questions about health and disease in the future ■

COLLECTIONS OF BLOOD SAMPLES
The samples in biobanks are smaller than those in historical collections, but there are more of them, 2015.

THE LIFEBLOOD OF SCIENCE

Lasse Boding • Biochemist and Coordinator at the Danish National Biobank

■ Countless blood samples taken from the cradle to the grave are transported to the Danish National Biobank. The drops of blood contain unique information and can be of benefit now, but also make life better for future generations. What follows is their path through the system.

A man sits in his doctor´s surgery waiting to have a blood test. His sleeve is rolled up. Warm blood and large quantities of biological information flow into a plastic tube. A small label with a barcode is attached to what is called a primary tube.
The same day all the clinic's blood samples are sent to Statens Serum Institut [the National Serum Institute] to be analysed. Once analysed, the remaining material is sent to the Danish National Biobank. Here a robot divides the blood sample into two parts: serum [the protein-rich part without blood cells] and blood coagulum [the part that contains DNA-rich white blood cells and red blood corpuscles]. The blood samples have endless uses. Blood contains such a large amount of information that there is no simple reading – in addition to which there is information in the material we still do not know how to access or understand.

Using an IT system, a message that supplies are on their way is now sent to the biobank's freezing robots. These fully automated robots scan the codes on the tubes and place them on one of the endless shelves. This is where the biological material waits until it is retrieved for a research mission.

A researcher has an idea and does a search on the Danish Biobank Register to find the right biological material needed for the research project. The register contains information on 22 million biological samples in Danish biobanks, and within minutes the researcher receives an answer on how many samples are available within the selected criteria, which can include the patient's gender, country of origin, year of birth, diagnosis, type of test, and much more.

Once the researcher has sourced the biomaterial they need, they apply to a Health Research Ethics Committee for permission to conduct the research project. Once the project is approved, the robots start retrieving the samples. Depending on the number of samples and where they are stored, the robots can retrieve 1,000-1,500 samples per day. The robots deposit the samples in a cold buffer room, where they are kept until a lab technician collects them.

The tests are packed and transported in a cool pack to the researcher who submitted the request for material. The researcher receives the samples, the analysis begins, and maybe a new research result comes to light. Yet another piece of the vast, strange health puzzle has been found ■

ROBOT AT THE BIOBANK
19m-long freezer at the Danish National Biobank with a custom-built robot that stores and then retrieves the blood tests when researchers need them, 2015.

“Think of it as an organic bank account. You put your biomaterial in and earn medical interest in the form of knowledge and therapies that grow out of that deposit – no monetary reward, just the potential that you might benefit from the accumulated data at some later date.”

Alice Park, Science journalist
‘10 Ideas Changing the World Right Now - Biobanks’, *Time Magazine*
2009

FREEZER AS EXHIBITION CASE
The freezer was used in the biobank project *Danish National Birth Cohort*. It displays the same kind of blood samples as those stored at the Danish National Biobank.

PKU BLOOD SAMPLE
Blood samples from newborn babies are taken on filter paper. Small cut outs of the paper are then used to test for congenital diseases. 2015.

THE PKU TEST AND THE BIOBANK

Bent Nørgaard Pedersen • Doctor and Professor in Biochemical Screening

■ A blood test is taken from all newborns in Denmark shortly after birth. The purpose of the test is to detect a series of congenital diseases where permanent damage can be avoided if treatment starts early. The sample is taken from the child´s heel on special filter paper and sent the same day to the Danish Centre for Neonatal Screening at Statens Serum Institut [The National Serum Institute]. Here they are screened for PKU [*Phenyl-KetonUria*] – which can cause brain damage – congenital low metabolism [*congenital hypothyrosis*], and 15 other syndromes or diseases.

Once checked, the blood sample is frozen and stored in the Neonatal Screening Biobank. Samples have been stored since 1982, and there are currently more than 2 million samples in the biobank. Each sample is labelled with a barcode number with no information identifying who it comes from. The only way to identify where the test comes from is via the PKU register, which can only be accessed by authorised healthcare professionals.

The purpose of keeping the samples is primarily to document that the test has been received and analysed, as well as making it possible to repeat or supplement the analyses. The tests are also used continuously to ensure the quality of the screening, as well as to develop new and improved methods of analysis.

Last but not least, the biobank is a national resource of major significance for research, for example into the causes of cleft lip and palate, cot death and premature birth. They are also used for projects researching the role played by environmental and genetic factors in the later development of psychological disorders and asthma. Their use in research is always contingent upon approval by the Danish Data Protection Agency, a scientific ethics committee and the biobank's steering committee. If someone does not want their sample used for research they can opt out of the register. It is also possible to have a sample destroyed.

Over the years there has been open and continuous dialogue with public authorities, politicians and the media regarding the ethical dimensions and uses of the samples, including their use in investigating rare diseases, to improve and develop methods of analysis, and in research projects.

The PKU sample is a unique sample in every person´s life, since it represents a kind of 'point zero' for any diseases that might develop later. It is increasingly used in investigating unexpected illness in children or later in life. These investigations take place on the basis of medical indications with the permission of the family for the benefit of the child and its family, as well as future generations ■

THE UNOBTRUSIVE GIANTS OF GENETIC RESEARCH

Thomas Söderqvist • Historian of Science and Professor

■ The gene chips in the last room of *The Body Collected* are among the most unobtrusive objects in the exhibition. They are negligible in size, and do not attract attention in the same way as the human specimens. But appearances can be deceptive: the gene chips are some of the most important objects in the exhibition. At least if you want to show how biomedical researchers study the body today.

The word gene chip is based on the word 'microchip', since its production is partly based on the methods used in the production of integrated circuits for computers. The gene chip is a small but central part of the complex biomedical analysis platform that makes it possible to investigate the body´s anatomy and function at the level of the genome. For example, which genes are present in a specific sample, whether there are variations [mutations] in the DNA sequences, and which genes are active.

The scientific basis for the analysis is hybridisation. DNA is a double-stranded molecule that can be split into matching single strands, which in turn can easily be hybridised into double strands. There are thousands of different artificial [and thereby known] fragments of single-strand DNA placed on the small chip; each short sequence has its own location on the chip, like on a chessboard. If a mixture of fragments of single-strand DNA from the test to be analysed are poured onto the chip, hybridisation will take place where the unknown test sequences match the known sequences.

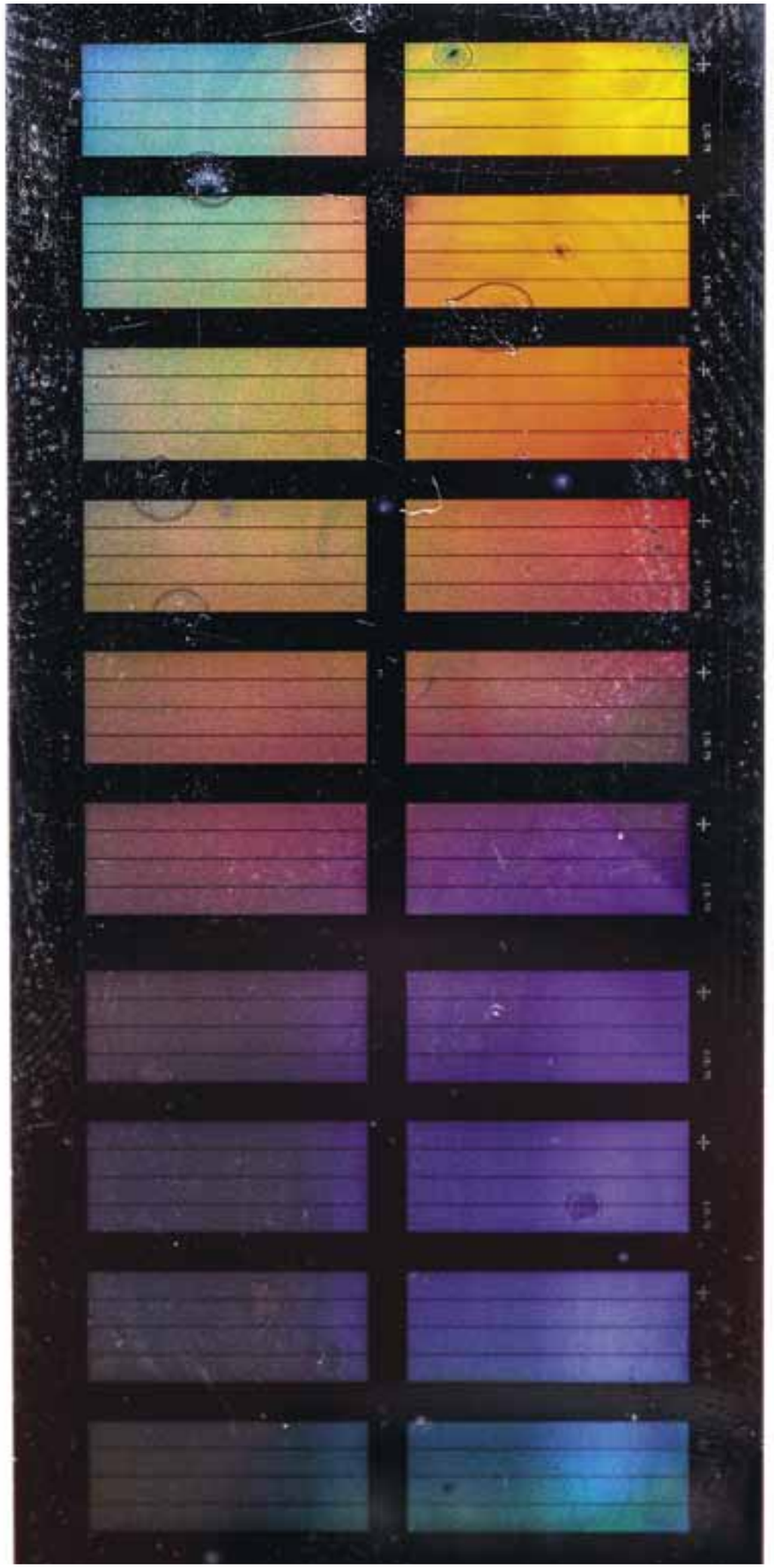
The whole platform consists of many more parts. In addition to the chip itself, it consists of the procedures and apparatus to extract, amplify and fluorescence stain the DNA, to measure the degree of hybridisation using a laser scanner, and to process and interpret the vast quantities of data and eliminate sources of error. In this way genes, mutations, active genes, etc. can rapidly be identified.

The first gene chip platform was developed on an experimental scale 20 years ago. Today it is a growing multi-billion industry that has made the mapping of biological organisms at DNA level possible. There are numerous variations of the technology, and the chips themselves are getting cheaper and cheaper. We have now reached next-generation gene chips, and their first generation predecessors have already become museum objects.

Despite its unobtrusiveness, the gene chip symbolises that the classical Enlightenment project has entered a new phase. During the industrial revolution mechanical and chemical engineers were responsible for progress. Now it is gene researchers who make it possible for us to control our biology. But they also hold the potential for an abuse of power that would make Orwell's *1984* look like a children´s fairy tale ■

GENE CHIP
Contains the entire genome of a human being [c. 3,2 billion bases], 2014.

BLOOD SAMPLE [above] The tube contains blood from a diagnostic test. The remaining blood is stored to double-check the diagnosis, as well as for research projects. The blood samples always contain more information than the results of the analyses we can perform today. Researchers collect bodily material to answer the questions we have today, but they store them because the material might also contain the answers to the questions of tomorrow. 2015. **TRACES OF MENTAL ILLNESS** [opposite page] Custom-made gene chip to measure 588,000 pre-selected variations in the DNA code. The goal is to find variations that have links to mental illness. 2014.



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DATA FROM GENETIC RESEARCH [previous page] The rows of letters show data deriving from a gene chip. They come from a study which investigated whether particular gene sequencies were active or not. A tiny part of the blood sample has thus been turned into data that is subsequently analyzed by computers. Although the process appears very different, it is similar to the way pathological collections of organs were used. In both cases, researchers try to find the signs in the body that relate to disease.

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EXHIBITION *THE BODY COLLECTED*

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Idea Ion Meyer, Thomas Söderqvist, Karin Tybjerg and Adam Bencard; **Project managers** Karin Tybjerg [2012 – 2014] and Bente Vinge Pedersen [2014 – 2015]; **Concept and research** Karin Tybjerg, Ion Meyer, Bente Vinge Pedersen, Niels Vilstrup, Adam Bencard, Malthe Boye Bjerregaard, Ane Pilegaard, Mads Kjædegaard, Nanna Arnfred and Martin Christiansen; **Architects** Martin Christiansen and Mads Kjædegaard; **Graphic design** Nanna Arnfred; **Curation of exhibition objects** Ion Meyer, Niels Vilstrup, Malthe Boye Bjerregaard, Karin Tybjerg and Bente Vinge Pedersen; **Collection** Karin Tybjerg, Malthe Boye Bjerregaard and Niels Vilstrup; **Texts** Bente Vinge Pedersen, Malthe Boye Bjerregaard, Thomas Söderqvist, Niels Vilstrup, Karin Tybjerg and Ion Meyer; **Translations** Jane Rowley and Thomas Söderqvist [exhibition captions]; **Films** Marika Seidler and Malthe Boye Bjerregaard; **Conservation** Ion Meyer, Annika Normann, Nanna Gerdes and Søren Lorentzen as well as the conservation department of the National Museum of Denmark; **Mounting of exhibits** Caroline Arendt, Nanna Gerdes and Annika Normann; **Production and building manager** Niels Vilstrup; **Light** Jan Jensen, Gunver Hansen; **Carpenter** Gribskov Inventarsnedkeri, N.A. Nielsen & Søn**; Metal work** Herfølge Kleinsmedie; Glazier Snoer og Sønner; **Decorating** Sten Valling; **Print** Uttenthal; **IT/AV** Mikkel Fredborg, Niels Plenge; **Exhibition assistent** Thomas Bjørkå; **Model builder** Lars Rothenborg**; Catalogue** Karin Tybjerg, Nanna Arnfred, Nicolai Howalt, Bente Vinge Pedersen, Ion Meyer, Malthe Boye Bjerregaard and Nanna Gerdes; **Principal investigator/grant holder** Thomas Söderqvist.

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